Rules and Regulations for the Classification of Offshore Units

Parts 1 to 11

July 2016

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Lloyd's Register

A guide to the Rules

and published requirements

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Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are generally published annually and changed through a system of Notices between releases.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Offshore Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

July 2016

A GUIDE TO THE RULES AND PUBLISHED REQUIREMENTS

RULES AND REGULATIONS FOR THE CLASSIFICATION OF OFFSHORE UNITS

Rules and Regulations for the Classification of Offshore Units

1 Introduction

1.1 The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

2 Numbering and Cross-References

2.1 A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

2.2 The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

2.3 References to other sets of Rules and Regulations published by Lloyd's Register Group Limited:

Criteria as detailed above have also been used when references are made to other sets of Rules, such as the *Rules and Regulations for the Classification of Ships*, (hereinafter referred to as the Rules for Ships) e.g., *see Pt 6, Ch 1, 3 Ergonomics of control stations* of the Rules for Ships. References to Lloyd's Register's *Rules and Regulations for the Classification of Ships* within these Rules are of the same year of publication.

2.4 References to Standards and Codes:

For undated references, e.g., IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features*, the latest edition of the referenced document (including any amendments) applies.

3 Rules updating

3.1 The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

3.2 Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

4 Rules programs

4.1 LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

4.2 July 2014

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UPDATE NOTES , Chapter 1

Section

1.1.1 The June 2013 version of these Rules and Regulations incorporates those changes contained in the Notices to the 2012 version.

1.1.2 Changes approved by the Board.

1.1.3 Editorial amendments have also been incorporated.

1.1.4 The July 2014 version of these Rules and Regulations supersedes the June 2013 version.

Section

1.2.1 The following explanatory note is offered to assist those concerned in the application of these Rules and Regulations.

1.2.2 **Explanatory Note**

1.2.3 Unit classification may be regarded as the development and worldwide implementation of published Rules and Regulations which, in conjunction with proper care and conduct on the part of the Owner and Operator, will provide for:

1.2.4 the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages;

1.2.5 the safety and reliability of the propulsion and steering systems; and

1.2.6 the effectiveness of those other features and auxiliary systems which have been built into the unit in order to establish and maintain basic conditions on board whereby appropriate cargoes and personnel can be safely carried whilst the unit is at sea, at anchor, or moored in harbour.

1.2.7 Lloyd's Register Group Limited (LR) maintains these provisions by way of the periodical visits by its Surveyors to the unit as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Should significant defects become apparent or damages be sustained between the relevant visits by the Surveyors, the Owner and Operator are required to inform LR without delay. Similarly any modification which would affect Class must receive prior approval by LR.

1.2.8 A unit is said to be in Class when the Rules and Regulations which pertain to it have, in the opinion of LR, been complied with, or when special dispensation from compliance has been granted by LR.

1.2.9 It should be appreciated that, in general, classification Rules and Regulations do not cover such matters as the unit's floatational stability, life-saving appliances, pollution prevention arrangements, and structural fire protection, detection and extinction arrangements where these are covered by the *International Convention for the Safety of Life at Sea, 1974,* its Protocol of 1978, and the amendments thereto, nor do they protect personnel on board from dangers connected with their own actions or movement around the unit. This is because the handling of these aspects is the prerogative of the National Authority with which the unit is registered. A great many of these authorities, however, delegate such responsibilities to the Classification Societies who then undertake them in accordance with agreed procedures.

Contents

■ *Section 1* Background

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

■ *Section 2* Governance

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:	Areas:
Australia (via Lloyd's Register Asia)	Benelux (via Lloyd's Register EMEA)
Canada (via Lloyd's Register North America, Inc.)	Central America (via Lloyd's Register Central and South America Ltd)
China (via Lloyd's Register Asia)	Nordic Countries (via Lloyd's Register EMEA)
Egypt (via Lloyd's Register EMEA)	South Asia (via Lloyd's Register Asia)
Federal Republic of Germany (via Lloyd's Register EMEA)	Asian Shipowners (via Lloyd's Register Asia)
France (via Lloyd's Register EMEA)	Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)	

Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

■ *Section 3* Technical Committee

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited
- Chairman of the Classification Committee of Lloyd’s Register Group Limited

Members Nominated by:

- Technical Committee
- Professional bodies representing technical disciplines relevant to the industry
- National and International trade associations with competence relevant to technical issues related to LR's business

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.
(b) A maximum of five further representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee as Nominated Members
(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR’s business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions and Codes, or Common Rules, Unified Requirements and Interpretations adopted by the International Association of Classification Societies, these may be implemented by LR without consideration by the Technical Committee, although any such changes will be provided to the Technical Committee for information.

Where changes to the Rules are required by LR to enable existing technical requirements within the Rules to be recognised as Class Notations or Descriptive Notes, these may be implemented by LR without consideration by the Technical Committee, although any such changes will be provided to the Technical Committee for information.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to the General Regulations, of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than the General

Regulations, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*
Naval Ship Technical Committee

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules. Where appropriate, Naval Ship Technical Committee may also recognise alternative LR Rule requirements that have been approved by the other Lloyd’s Register Technical Committee as adjunct to the Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, the General Regulations of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than the General Regulations, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*
Applicability of Classification Rules and Disclosure of Information

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System. LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

Section 6
Ethics

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

Section 7
Non-Payment of Fees

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

Section 8
Limits of Liability

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section *Pt 1, Ch 1, 8 Limits of Liability 8.2* above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ List of abbreviations

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
BS	British Standard (issued by British Standard Institution)
DFF	Design Fatigue Factors
DP	Dynamic Positioning
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
FLNG	Floating LNG
FPSO	Floating Production, Storage and Off-loading installation
FRU	Floating Re-gasification Unit
FSRU	Floating Storage and Re-gasification Unit
FSO	Floating Storage and Offloading Vessel
FSU	Floating Storage Unit
GMDSS	Global Maritime Distress and Safety System
HCA	Helideck Certification Agency
IACS	International Association of Classification Societies
ILO	International Labour Organisation
IMO	International Maritime Organization
ISO	International Organisation for Standardisation
ISM code	International Safety Management Code
LNG	Liquefied Natural Gas
LOLER	Lifting Operations and Lifting Equipment Regulations (UK)
MARPOL	International Convention on the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee (IMO)
MODU	Mobile Offshore Drilling Unit
MPI	Magnetic Particle Inspection
NACE	National Association of Corrosion Engineers
NDE	Non- Destructive Examination

NDT	Non-Destructive Testing
PWHT	Post Weld Heat Treatment
RP	Recommended Practice
RT	Radiographic Testing
SCF	Stress Concentration Factor
SIGTTO	Society of International Gas Tanker and Terminal Operators Ltd
SMB	Single Buoy Mooring
SCE	Safety Critical Element
SCR	Safety Case Regulations
SMS	Safety Management System
SOLAS	International Convention on the Safety of Life at Sea
SPM	Single Point Mooring
STWC	International Convention on Standards of Training, Certification and Watch-keeping for seafarers
TLP	Tension Leg Platform
WPS	Welding Procedure Specification

■ *Section 1*
Conditions for classification

1.1 Application

1.1.1 The *Rules and Regulations for the Classification of Offshore Units* (hereinafter referred to as the Rules for Offshore Units) are applicable to units engaged in offshore operations including drilling, oil/gas production and storage, accommodation and other support functions and which generally operate within the territorial waters of a Coastal State Authority but excluding the ship types defined in Part 4 of the *Rules and Regulations for the Classification of Ships*.

1.1.2 An offshore unit may be assigned one of the two following class notations:

OI

This notation is applicable to floating offshore installations that operate at a fixed geographic location for their entire service life, see 1.2.

The following asset types are covered by the **OI** notation:

- column-stabilised semi-submersible floating production units (FPU);
- self-elevating (jack-up) production units;
- jack up accommodation
- crude oil floating production, storage and offloading ship and barge type units;
- crude oil floating storage and offloading ship and barge type units;
- liquefied gas floating production and storage ship and barge type units;
- liquefied gas floating storage ship and barge type units;
- tension leg units;
- deep draught caisson units;
- buoys.

OU

This notation is applicable to mobile offshore units that operate at and transit between different locations, see 1.3.

The following asset types are covered by the **OU** notation:

- column-stabilised semi-submersible units (mobile offshore drilling units, heavy lift vessels, accommodation units and diving support vessels);
- self-elevating (jack-up) mobile offshore drilling units;
- surface type units (drill ships, twin-hull heavy lift vessels);
- wind turbine installation vessels
- tender barge.

The following Parts, Chapters and Sections are only applicable to floating offshore installations at a fixed location:

- *Pt 1, Ch 2, 1.2 Floating offshore installations at a fixed location*
- *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*
- *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures*
- *Pt 3, Ch 14 Foundations*
- *Pt 9 CONCRETE UNIT STRUCTURES*
- *Pt 10 SHIP UNITS*
- *Pt 11 PRODUCTION, STORAGE AND OFFLOADING OF LIQUEFIED GASES IN BULK*

1.1.3 The following Parts, Chapters and Sections are only applicable to mobile offshore units:

- *Pt 1, Ch 2, 1.3 Mobile offshore units*
- *Pt 3, Ch 5 Fire-fighting Units*
- *Pt 3, Ch 16 Wind Turbine Installation and Maintenance Vessels and Liftboats*

1.1.4 The basic Lloyd's Register (LR) class notation for an installation would normally include:

- Description of the installation, facilities provided and field location.
- Structure and marine systems.
- Positional mooring system.
- Propulsion (where applicable).

1.1.5 The notation PPF (Process Plant Facility) can be assigned to process facilities on production and oil storage units – *see Pt 1, Ch 2, 2.4 Class notations (hull/structure) 2.4.13*. These process facilities will be installed on a unit with a LR classed hull, classed marine systems and a classed mooring system.

1.1.6 If the process facilities are not requested to be classed (no PPF notation), classification of the unit will be subject to alternative applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements. These process facilities will be installed on a unit with a LR classed hull, classed marine systems and a classed mooring system.

1.1.7 Whether the PPF notation is assigned or not, the process facilities will require to be surveyed or verified throughout the unit's service life to maintain classification.

(a) The process plant facilities include the equipment, supporting structure and systems used for oil and gas production.

1.1.8 As an option, the Owner may request that LR consider performance standards determined by risk assessment as the basis for design, construction, and inspection/ maintenance. Guidelines for classification of an offshore installation using risk assessment to determine performance standards are provided in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*. Definitions of risk assessment terms are also given in Chapter 5. Performance standards determined by risk assessment may be accepted by LR as the alternative basis for classification, provided that:

- LR approval is obtained at all key stages detailed in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*; and
- LR verifies that all elements which are critical to the safety and integrity of the installation meet their required performance standards, as outlined in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*.

Where a Formal Safety Assessment or Safety Case is prepared as a requirement of a National Administration or of the Owner, the Owner may request that LR consider the results as a basis for determining the performance standards to be used for classification. In such cases, the Formal Safety Assessment or Safety Case will be reviewed by LR to confirm that it considers all hazards to the safety and integrity of the installation which are relevant to classification. The Guidelines in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards* will then apply.

1.1.9 For units which are outside the scope of application of the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* and/or the international conventions referred to in *Pt 1,*

Ch 2, 1 Conditions for classification , compliance with any prescribed standards of the applicable Coastal State Authority is to be demonstrated by the issue of appropriate certification by that Coastal State Authority or LR where so authorised.

1.2 Floating offshore installations at a fixed location

1.2.1 Floating offshore installations at a fixed location will be assigned the class notation **OI**.

1.2.2 LR classed tankers being converted for service as a floating offshore installation at a fixed location in accordance with the requirements of these Rules will be eligible for class notation **OI**. Special consideration will be given to the class notation assigned when the tanker to be converted is not classed with LR, see also *Pt 10 SHIP UNITS*.

1.3 Mobile offshore units

1.3.1 Mobile offshore units will be assigned the class notation **OU**.

1.3.2 The adequacy of sea bed conditions with respect to bearing capacity, resistance to possible sliding and anchor holding capacity is not covered by classification. In particular, for self-elevating units, it is the responsibility of the Owner to be satisfied that the sea bed conditions are suitable to allow the legs to be safely and adequately preloaded.

1.3.3 It is the Owner's responsibility to comply with any applicable regulations of the Coastal State Authorities in the areas of operation. Compliance with the prescribed standards of the applicable National Administration is to be demonstrated by the issue of appropriate certification by the National Administration or LR where so authorised. *See* also *Pt 1, Ch 2, 1.4 General*.

1.3.4 to operate for prolonged periods adjacent to other offshore installations which are being used for hydrocarbon exploration or production, it is the Owner's responsibility to comply with the requirements of the appropriate National Administration and LR is to be advised at the approval stage so that classification aspects relating to safety are taken into account, see *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*. Special consideration will be given to existing units with regard to class.

1.4 General

1.4.1 Offshore units built in accordance with LR's Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class on the*Class Direct* website and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for materials, structure, machinery, equipment and other safety considerations.

1.4.2 Units designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being considered by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage, in order that a basis for acceptance of the standards may be agreed.

1.4.3 The Classification Committee, in addition to requiring compliance with LR's Rules, or other agreed performance standards, may require to be satisfied that units are suitable for geographical or other limits or conditions of the service contemplated.

1.4.4 Although the specified design environmental criteria on which classification is based are the responsibility of the Owner, assessment by LR of a unit's suitability for service at a particular offshore location will be undertaken and agreed before approval.

1.4.5 Loading conditions and other preparations required to permit a unit (whether self-propelled or not) with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.4.6 Any damage, defect, breakdown or grounding, serious deficiency, detention or arrest, or refusal of access which could invalidate the conditions for which class has been assigned is to be reported to LR without delay.

1.4.7 The Owner is solely responsible for the operation of the unit. The Rules are framed on the understanding that the unit will be properly loaded and operated, and the environmental conditions are no more severe than those agreed for the design basis and approval, without prior agreement of LR.

1.4.8 When longitudinal strength calculations are required for ship units and other surface type units, loading guidance information is to be supplied to the Master by means of a Loading Manual and in addition, when required, by means of a loading instrument, *see* also 1.4.9. Loading Manuals and loading instruments for surface type units are to be in accordance with *Pt 4, Ch 4, 8 Transport and handling of limited amounts of hazardous and noxious liquid substances in bulk* of the Rules for Ships.

1.4.9 It will be the responsibility of the Owner to provide instructions and set down limits for the operation of the unit to ensure that the loading and environmental conditions on which classification is based will not be exceeded. These instructions and limitations are to be contained in the Operations Manual (or a Loading Manual for ship units and other surface type units) which is to be retained on board the unit. The Owner should ensure that the Manual is kept up to date and contains appropriate data required by the relevant National Administration.

1.4.10 For units, the arrangements and equipment of which are required to comply with the requirements of the:

- *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A. 1023(26)* (2009 MODU Code);
- *Load Lines Convention*;
- *SOLAS - International Convention for the Safety of Life at Sea* and its Protocol of 1978;
- *Articles of the International Convention for the Prevention of Pollution from Ships, 1973,* as modified by the Protocol of 1978 relating thereto;
- *IBC Code - International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in BulkAmended by Resolution MEPC.225(64);* and applicable Amendments thereto.

The Classification Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the*International Safety Management (ISM) Code – Resolution A.741(18)* may be issued by an organisation complying with *IMO Resolution A. 739(18) – Guidelines for the Authorization of Organizations Acting on Behalf of the Administration – (Adopted on 4 November 1993)Amended by Resolution MSC.208(81)* and authorised by the National Administration with which the unit is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Administration with which the unit is registered. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided that this is recognised in a formal Dual Class Agreement with LR and provided that the other Society is also authorised by the National Administration. In the event of a National Administration withdrawing any unit's Convention Certificate (referred to in this Section), then the Classification Committee may suspend the unit's class. If a unit is removed from the National Administration's Registry for non-compliance with the Conventions or Classification requirements referred to herein then the Classification Committee will suspend the unit's class. In the event of ISM Code certification being withdrawn from a unit or Operator, the Classification Committee will suspend the unit's class.

1.4.11 Where the National Administration has no prescribed standards for units which are outside the scope of application of the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* and/or the International Conventions referred to in 1.4.10 or their standards are not considered acceptable for classification purposes, LR will apply the relevant parts of the 2009 MODU Code/Convention Regulations and other recognised Standards as applicable to the intended use of the unit as a prerequisite to classification.

1.4.12 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new unit or newly installed on an existing unit, then the system is to be certified in respect of longitudinal strength in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs.*

1.4.13 Where an onboard computer system having stability computation capability is provided on a new unit, the system is to be certified in respect of stability aspects, in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the unit on which it is installed.

1.4.14 When a unit, fitted with a conventional rudder, is to operate for a prolonged period at a fixed location, it is the Owner's responsibility to ensure that suitable arrangements are provided to prevent damage to the steering gear. Special consideration will be given to the requirements for the steering gear and propelling machinery, see *Pt 4, Ch 10 Steering and Control Systems*, and *Pt 5, Ch 6 Main Propulsion Shafting* and *Pt 5, Ch 19 Steering Gear*.

1.4.15 Where a unit has been detained by Port State Control, the Owner is to advise LR immediately, in order to arrange the attendance of a Surveyor.

1.5 Interpretation of the Rules

1.5.1 The interpretation of the Rules is the sole responsibility, and is at the sole discretion, of LR. Any uncertainty in the meaning of the Rules is to be referred to LR for clarification.

1.5.2 In many instances, these Rules require that particular components, systems and equipment, etc., must also comply with applicable Sections of the Rules for Ships. Every effort has been made to avoid potential conflicting requirements; however, where such a conflict becomes apparent, the requirements of these Rules shall take precedence.

1.6 Advisory services

1.6.1 The Rules do not cover certain technical characteristics, such as stability, hull vibration, etc., but advice may be given on such matters without any assumption of responsibility for such advice.

1.7 Legislative verification

1.7.1 LR has been authorised by a number of National Administrations to carry out verification of offshore units and installations in accordance with statutory Regulations. Full details will be supplied to Owners and other interested parties on request. See also*Pt 1, Ch 2, 2.8 Class notation (Verification Schemes)* and *Pt 1, Ch 4 Verification in Accordance with National Regulations for Offshore Installations*.

1.7.2 LR has also been authorised on behalf of National Administrations of a large number of nations to issue certain statutory, safety and other certificates. LR is willing to act, when requested, in respect of such certification.

1.7.3 When machinery and equipment are to comply with EC Directives, LR as a notified body can issue EC Type Certification in accordance with LR's appointment. Full details will be supplied to manufacturers and other interested parties on request.

■ *Section 2*
Definitions, character of classification and class notations

2.1 General definitions

For the purpose of class notations, the definitions given in 2.1.1 to 2.1.24 will apply.

2.1.1 **Accommodation unit** is a support unit whose primary function is to provide accommodation for more than twelve offshore personnel who are not crew members or passengers.

2.1.2 **Buoy units** are floating units used as a mooring facility for a ship or an offshore unit and are secured by a flexible tether or tethers to the sea bed.

2.1.3 **Clear water.** Water having sufficient depth to permit the normal development of wind generated waves.

2.1.4 **Coastal State Authority** is the Authority responsible for the safety standards of units operating in or adjacent to their territorial waters.

2.1.5 **Column-stabilised semi-submersible units** have working platforms supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed, see also 2.2.3.

2.1.6 **Deep draught caisson units** are floating units which operate at a deep draught in relation to their overall depth.

2.1.7 **Disconnectable units** are self-propelled floating units which normally operate at a fixed location but are designed to disconnect from their moorings in order to avoid hazards or extreme storm conditions.

2.1.8 **Fetch.** The extent of clear water across which a wind has blown before reaching the unit.

2.1.9 **Floating offshore installation.** For classification a floating offshore installation is an offshore unit, and its integral associated offshore mooring facility, that operates at a fixed geographic location for its entire service life. When the mooring facility is independent of the offshore unit, e.g., buoy or mooring tower, classification of the floating offshore installation will normally be subject to the buoy or mooring tower being classed separately by LR unless agreed otherwise by the Classification Committee, see also *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES* and *Pt 4, Ch 4 Structural Unit Types*.

2.1.10 **Mobile offshore unit.** For classification a mobile offshore unit is an offshore unit that operates at and transits between different locations.

2.1.11 **National Administrations** are those Authorities defined in 2.1.4 and 2.1.12.

2.1.12 **National Authority** is the Marine Authority in the country in which a unit is registered.

2.1.13 **Offshore unit** means a unit engaged in offshore operations including drilling, oil production and storage, accommodation and other support functions and which generally operates within the territorial waters of a flag state, but excluding the ship types defined in *Pt 4 Ship Structures (Ship Types)* of the Rules for Ships.

2.1.14 **Owner.** In the context of these Rules, the Owner is defined as the party responsible for the unit, including its operation and safety.

2.1.15 **Positional mooring.** Station-keeping by means of multi-leg mooring systems with or without thruster assistance. Other definitions for mooring facilities are contained in *Pt 3, Ch 10 Positional Mooring Systems*.

2.1.16 **Reasonable weather.** Wind strengths of force six or less in the Beaufort scale, associated with sea states sufficiently moderate to ensure that green water is taken on board the unit's weather deck at infrequent intervals only, or not at all.

2.1.17 **Self-elevating units** are units which are designed to operate as sea bed-stabilised units in an elevated mode. These units have a buoyant hull with movable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. See also *Pt 1, Ch 2, 1.4 General*.

2.1.18 **Self-propelled** means that the unit is designed for unassisted sea passages and is fitted with propelling machinery in accordance with LR Rules.

2.1.19 **Sheltered water.** Water where the fetch is six nautical miles or less.

2.1.20 **Ship units** are mono-hull surface type units engaged in production and/or oil/gas storage/offloading while permanently moored at offshore locations with a ship or barge hull form. Such units may be self-propelled or be built without primary propelling machinery.

2.1.21 **Specially considered** (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

2.1.22 **Support units** are units whose primary function is to support offshore installations. They are normally engaged in one or more of the following functions:

- crane operations, fire-fighting, diving operations, maintenance, construction, pipelaying and accommodation.

2.1.23 **Support vessel.** Alternative name for a support unit as defined in 2.1.21.

2.1.24 **Surface type units** are units with a ship or bargetype displacement hull of single or multiple hull construction intended for operation in the floating condition.

2.1.25 **Tension-leg units** are offshore units which are linked to a fixed foundation by means of tensioned mooring tethers or other parallel, near vertical, connections in such a manner that the unit is constrained to float at a draught greater than that consistent with its displacement when floating freely.

2.2 Modes of operation

2.2.1 A mode of operation is a condition or manner in which a unit may operate or function while on location or in transit. From the classification aspect, the modes of operation of a unit should include the following:

(a) **Operating condition**

The condition when a unit is on location, for the purpose of carrying out its primary design operations, and the combined environmental and operational loadings are within the appropriate design limits established for such operations. The unit may be either afloat or supported on the sea bed, as applicable.

(b) **Survival condition**

A severe storm condition during which a unit may be subjected to the most severe environmental loadings for which the unit is designed. Production, drilling or similar operations may have been discontinued due to the severity of the environmental loadings. The unit may be either afloat or supported on the sea bed, as applicable.

(c) **Transit condition**

All unit movements from one geographical location to another.

(d) **Site-installation and re-floating condition**

This condition is only applicable to self-elevating units. This condition comprises elevating and lowering the legs, touchdown of the legs/bottom mats with the sea bed and preloading.

For ship units and other surface type units, the modes of operation will be defined by the loading conditions stated in the approved loading manual.

2.2.2 **Linked** means connected while operating to a single point mooring facility, fixed structure or otherwise attached or resting on the sea bed.

2.2.3 **Sea bed-stabilised** means designed to operate under normal operating and survival conditions while the footings, mat or pontoons rest on the sea bed.

2.3 Character Symbols

2.3.1 All units, when classed, will be assigned one or more character symbols, as applicable. For the majority of floating offshore installations at a fixed location, the character assigned will be **✠ OI 100AT** or **✠ OI 100AT (1)**. For the majority of mobile offshore units, the character assigned will be **✠ OU 100A1**.

2.3.2 A full list of character symbols for which offshore units may be eligible is as follows:

✠ = This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Classification Committee.

$\overline{✠}$ = This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in accordance with plans approved by another recognised classification society.

$\dot{✠}$ = This distinguishing mark, will be assigned to units built under supervision of another IACS member society and later assigned class with LR. For such units the class notations will be reviewed separately and equivalent notations will be assigned.

OI = These character letters will be assigned to all units which have been built or accepted into Class in accordance with the requirements prescribed for floating offshore installations at a fixed location in LR's Rules and Regulations the Classification of Offshore Units.

OU = These character letters will be assigned to all units which have been built or accepted into Class in accordance with the requirements prescribed for mobile offshore units in LR's Rules for Offshore Units.

100 = This character figure will be assigned to all units considered suitable for operating at exposed locations offshore or for sea-going service.

A = This character letter will be assigned to all units which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 = This character figure will be assigned to:

(a) Units having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with *Pt 4, Ch 9 Anchoring and Towing Equipment* of the Rules.

(b) Units classed for special service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

(c) Units equipped with a classed dynamic positioning system which has sufficient power, redundancy of components and duplication of controls to supplement or replace the anchoring equipment on board such that the combined system/equipment is approved by the Classification Committee as equivalent to the anchoring equipment necessary during voyages, transfer moves or under normal operating conditions, see *Pt 3, Ch 9 Dynamic Positioning Systems*.

T = This character letter will be assigned to floating offshore installations at a fixed location which have, in good and efficient condition, anchoring, mooring or linking equipment in accordance with the Rules, see *Pt 3, Ch 10 Positional Mooring Systems*.

N = This character letter will be assigned to installations on which the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

2.3.3 Non-propelled units which are required to make transit voyages from one operating site to another are to be fitted with towing arrangements in accordance with *Pt 4, Ch 9 Anchoring and Towing Equipment*.

2.3.4 Self-propelled units which are required by the Owners to make transit voyages from one operating location to another or are disconnectable to avoid severe storms or hazards are to comply with the requirements of 2.3.2 for the assignment of the

character figure **(1)** which will be assigned after the character letter **T**. The disconnection or reconnection of a disconnectable unit is to be to the satisfaction of the Surveyor. For disconnections to avoid severe storms or hazards see 3.8.2.

2.3.5 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the unit will be liable to be withheld.

2.3.6 The character figure **100** will be omitted for units operating in protected waters such as harbours, inland lakes, etc., and the requirements of the Rules may be relaxed or otherwise amended as considered appropriate by the Classification Committee.

2.3.7 Units will not be classed unless the primary propelling machinery and/or the essential auxiliary machinery of the unit is also classed.

2.4 Class notations (hull/structure)

2.4.1 When considered necessary by the Classification Committee, or when requested by an Owner and agreed by the Classification Committee, a class notation will be appended to the character of classification assigned to the unit. This class notation will consist of one of, or a combination of, the following:

- A type notation.
- A special features notation.
- A special duties notation.
- A specified operating area.
- A service restriction notation.
- An operating limits notation.

A table summarising the notations given in this Part of the Rules and other notations listed elsewhere in the Rules can be found in Part 1, Appendix 1.

2.4.2 **Type notation**. A notation indicating that the unit has been arranged and constructed in compliance with the particular Rules intended to apply to that type of unit, e.g., Mobile offshore drilling unit or Floating Production Unit. Typical type notations are defined in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

2.4.3 **Special duties notation**. A notation indicating that the unit has been designed, modified or arranged for special duties other than those implied by the type notation, e.g., oil exploration or well intervention. Units with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

2.4.4 **Special features notation**. A notation indicating that the unit incorporates special features which significantly affect the design, e.g., **DRILL** or**PPF**. See 2.4.13.

2.4.5 Operating limits notation. A notation indicating the significant design criteria on which approval of the unit is based, e.g.:

- Maximum operating environmental design limits for semi-submersible units and self-elevating units.
- Limiting sea state and/or wind speed during which a unit may remain moored to a single point mooring.

2.4.6 **Service restriction notation**. A notation indicating that the unit has been classed on the understanding that it will be operated only in suitable areas or conditions which have been agreed by the Classification Committee, e.g., protected waters service.

2.4.7 Service restriction notations will generally be assigned in the form shown in 2.4.9 and 2.4.10, but this does not preclude Owners requesting special consideration for other forms in unusual cases.

2.4.8 Where a service notation is applicable, certain exemptions may be granted. Where these affect statutory requirements, such as Load Lines, the Owner is to obtain the authorisation of the Flag State. Such exemptions are to be recorded on the Class certificate and any applicable statutory certificate.

2.4.9 **Protected waters service**. Service in sheltered water adjacent to sand banks, reefs, breakwaters or other coastal features.

2.4.10 **Specified operating area**. A notation indicating that the unit has been classed on the understanding that it will be operated only in suitable areas which have been agreed by the Classification Committee, e.g., North Sea service (Abbot Field) or Black Sea service.

2.4.11 A typical example of character of a hull class notation for a floating offshore installation at a fixed location is:

✠ **OI 100AT** Floating Production, Storage and Offloading Unit, **PPF**, North Sea service (Alma Field), OIWS, LI.

A typical example of a hull class notation for a mobile offshore unit is:

✠ **OU 100A1** Mobile offshore drilling unit, **DRILL**, Gulf of Mexico service.

2.4.12 The assigned character symbols of class and the appropriate class notations will be entered in the Class Direct website. For all unit types except ship units and other surface type units, the limiting structural design criteria on which classification is based will also be entered on the Class Direct website.

2.4.13 The following special features class notations may be assigned as considered appropriate by the Classification Committee:

PPF This notation will be assigned to units which have specialised structures and an installed process plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations or recognised Codes and Standards accepted by LR, *see Pt 3, Ch 8 Process Plant Facility*.

DRILL This notation will be assigned to units which have specialised structures and an installed drilling plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, see *Pt 3, Ch 7 Drilling Plant Facility*.

DROPS This notation will be assigned to units which have preventive measures to protect personnel from the hazards of dropped objects in accordance with *Pt 3, Ch 7, 10 Risks to personnel from dropped objects*.

PM This notation will be assigned to mobile offshore units which have a positional mooring system which complies with the requirements of *Pt 3, Ch 10 Positional Mooring Systems*.

PMC This notation will be assigned to mobile offshore units which have a positional mooring system for mooring in close proximity to other vessels or installations which complies with the requirements of *Pt 3, Ch 10 Positional Mooring Systems*.

PRS This notation will be assigned to units which have a product riser system which has been constructed, installed and tested under LR's Special Survey, in accordance with LR's Rules, see *Pt 3, Ch 12 Riser Systems*.

OIWS This notation for In-Water Survey may be assigned to a unit where the applicable requirements of LR's Rules and Regulations are complied with, see*Pt 1, Ch 3, 4.3 In-water surveys*,*Pt 3, Ch 1, 2.1 General* and *Pt 8, Ch 1, 1.3 External zone protection*.

2.4.14 The **OIWS** notation may be assigned to existing units on satisfactory completion of the Survey, provided that the applicable requirements of LR's Rules and Regulations are complied with.

2.4.15 **LI**. This notation will be assigned to surface type units where an approved loading instrument has been installed as a classification requirement.

2.4.16 Details of unit types and additional special features class notations for which special Rules apply are incorporated in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*, see also 2.8.

2.4.17 The following class notations may be assigned to ship units as considered appropriate by the Classification Committee:

(a) **ShipRight SDA**. This notation can be assigned to both new build ship units and tanker conversions when structural strength of the hull has been assessed for environmental loads assuming unrestricted service as a ship. The structural strength of the hull is to be verified using the finite element method.
(b) **ShipRight RBA**. The response based analysis (structure) class notation will be assigned to both new build ship units and tanker conversions when structural strength has been verified by performing direct calculations (finite element analysis) for hull structure in accordance with the *ShipRight Procedure for Ship Units*.
(c) **ShipRight FDA (years)**. The fatigue design assessment (design life) class notation will be assigned to both new build ship units and tanker conversions when fatigue life of critical connection details has been assessed in accordance with the *ShipRight Procedure for Ship Units*.
(d) **ShipRight CM**. The construction monitoring class notation will be assigned to new build ship units and tanker conversions when agreed enhanced inspection measures have been implemented and verified during construction to ensure that at critical locations the connection details are within the agreed tolerances. Critical locations are to be agreed with LR on a case by case basis. A plan showing critical locations is to be submitted for approval, in accordance with the *ShipRight Procedure for Ship Units*.
(e) **CSR**. This notation indicates that the structure has been verified as fully compliant with IACS CSR. This notation cannot be assigned retrospectively. It may only be assigned to new build units or units which already had a **CSR** notation assigned before conversion or redeployment.

Assignment of these notations will be project-specific and will depend on whether the unit is a new build or tanker conversion, whether the unit is permanently moored or disconnectable and the site-specific environmental conditions, see Table 2.4.1. The

design procedures given in the *ShipRight Procedure for Ship Units*, are required to be applied for hull strength, fatigue and construction aspects. Assignment of these notations will be specially considered for other surface type units.

Table 2.2.1 Application of ShipRight Notations

ShipRight notation	Redeployment and conversion		New build	
	Moderate environment	Harsh environment	Moderate environment	Harsh environment
RBA	Either RBA or SDA is required	Mandatory	Either RBA or SDA is required	Mandatory
FDA (years)	Mandatory	Mandatory	Mandatory	Mandatory
CM	Mandatory	Mandatory	Mandatory	Mandatory
SDA	Either RBA or SDA is required	N/A	Either RBA or SDA is required	N/A

2.4.18 The **ShipRight SDA** notation may be retained by LR Classed tankers after conversion to a floating offshore installation at a fixed location for service in a moderate environment as defined in*Pt 10, Ch 1, 1.2 Definitions* and 2.4.15.

2.4.19 The following class notation may be assigned to column-stabilised semi-submersible units as considered appropriate by the Classification Committee:

(a) **ShipRight RBA**. The response based analysis class notation will be assigned when the structural strength has been verified by performing direct calculations (finite element analysis) for hull structure in accordance with the *ShipRight Procedure for Semi-submersibles*.

(b) **ShipRight FDA3 (years)**. The fatigue design assessment (design life) class notation will be assigned to column-stabilised semi-submersible units when fatigue life of critical connection details has been assessed in accordance with the *ShipRight Procedure for Semi-submersibles.*

(c) **ShipRight CM**. The construction monitoring class notation will be assigned to column-stabilised semi-submersible units when agreed enhanced inspection measures have been implemented and verified during construction to ensure that at critical locations the connection details are within the agreed tolerances. Critical locations are to be agreed with LR on a case by case basis. A plan showing critical locations is to be submitted for approval, in accordance with the *ShipRight Procedure for Semi-submersibles*.

2.4.20 Special consideration will be given to assignment of additional notations given in *Pt 1, Ch 2 Classification Regulations* of the Rules for Ships at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.5 Class notations (machinery)

2.5.1 The following class notations are associated with machinery construction and arrangements, and may be assigned as considered appropriate by the Classification Committee:

✠ **Lloyd's RGP** This notation will be assigned when a regasification system and arrangements have been constructed, installed and tested under Lloyd's Register's (hereinafter referred to as LR's) Special Survey and in accordance with the relevant requirements of the Rules.

✠ **Lloyd's RGP+** This notation will be assigned when a regasification system and arrangements have been constructed, installed and tested under LR's Special Survey and in accordance with the relevant requirements of the Rules and the system is configured to allow continuing operation in the event of a single failure.

✠ **OMC** This notation will be assigned to non-propelled units when the essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]**OMC** This notation will be assigned to non-propelled units when:

- the pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and electrical power generation and other auxiliary machinery for essential services are in compliance with LR's Rules and supplied with the manufacturer's certificate.
- the system arrangement of essential auxiliary machinery is appraised and found to be acceptable to LR.

OMC This notation (without ✠) will be assigned to existing non-propelled units that will be accepted or transferred into LR class when:

- the essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

✠**LMC** This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]**LMC** This notation will be assigned to self-propelled units when:

- the propelling arrangements for propellers, propulsion shafting and multiple input/output gearboxes, steering systems, pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and gearing arrangements for propulsion and electrical power generation and other auxiliary machinery for essential services are in compliance with LR Rules and supplied with the manufacturer's certificate.
- the system arrangements of propelling and essential auxiliary machinery are appraised and found to be acceptable to LR.

LMC This notation (without ✠) will be assigned to existing self-propelled units that will be accepted or transferred into LR class when:

- the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

IGS This notation will be assigned, when a unit having facilities for the storage of crude oil in bulk is fitted with an approved system for producing gas for inerting the crude oil storage tanks.

2.5.2 The following class notations are associated with the machinery control and automation, and may be assigned as considered appropriate by the Classification Committee:

UMS This notation may be assigned when the arrangements are such that the unit can be operated with the machinery spaces unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of the unit's operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IP This notation may be assigned to a unit classed with LR when the arrangements of the machinery are such that the propulsion equipment and all the essential auxiliary machinery is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment has been arranged, installed and tested in accordance with LR's Rules.

2.5.3 The following special features class notations are associated with dynamic positioning arrangements and may be assigned as considered appropriate by the Classification Committee, see *Pt 3, Ch 9 Dynamic Positioning Systems*:

DP(CM) This notation may be assigned when a unit is fitted with centralised remote manual controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or is equivalent thereto.

DP(AM) This notation may be assigned when a unit is fitted with automatic main and manual standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or that it is equivalent thereto.

DP(AA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

DP(AAA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping, together with an additional/emergency automatic control unit located in a separate compartment and with position

reference systems and environmental sensors. It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

2.5.4 The dynamic positioning notations in 2.5.3 can be supplemented with a Performance Capability Rating notation **(PCR)**. This rating indicates the calculated percentage of time that a unit is capable of holding heading and position under a standard set of environmental conditions (North Sea), see *Pt 3, Ch 9 Dynamic Positioning Systems*.

2.5.5 Machinery class notations will not be assigned to units the hull/structure of which is not classed or intended to be classed with LR.

2.5.6 The notations ✠ **LMC**, [✠] **LMC** and **LMC** (without ✠) will not, in general, be assigned to non-self-propelled vessels.

2.5.7 Special consideration will be given to assignment of the additional notations given in *Pt 1, Ch 2 Classification Regulations* of the Rules for Ships, at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.6 Lifting Appliances

2.6.1 See *Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

2.7 Class notations (environmental protection)

2.7.1 The following class notations are associated with the design and operation of a unit and may be assigned as considered appropriate by the Classification Committee, on application from the Owners, see *Pt 7, Ch 11 Arrangements and Equipment for Environmental Protection (ECO Class Notation)* of the Rules for Ships:

ECO This notation will be assigned when a unit is designed and operated in accordance with the relevant requirements of the Rules for Ships.

ECO (TOC) This notation will be assigned when the environmental protection arrangements are in accordance with the requirements of another recognised classification society and are essentially equivalent to Rule requirements and the unit is operated in accordance with the relevant requirements of the Rules for Ships.

2.8 Class notation (Verification Schemes)

2.8.1 When an Owner requests classification based on a Formal Safety Assessment, see 1.2.3, and verification is carried out by LR in accordance with the Regulations of a National Administration and the Guidelines in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*, the class notation **CAV** may also be assigned to classed installations as considered appropriate by the Classification Committee. The notation will be maintained subject to periodical surveys during operation as detailed in *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*.

2.9 Descriptive Notes/Supplementary Character

2.9.1 In addition to any class notations, appropriate descriptive qualification notes may be entered on the Class Direct website indicating the type of unit in greater detail than is contained in the class notation, and/or providing additional information about the design and construction, e.g., semi-submersible. A descriptive qualification is not a LR classification notation and is provided solely for information. Examples of descriptive notes are:

Semi-submersible	
Tanker conversion	Unit based on converted tanker
Turret mooring	Turret mooring (internal/external)
Spread mooring	Multi-point positional mooring
Disconnectable unit	Unit can be disconnected from fixed mooring
Helideck	Helicopter deck approval
COW (LR)	Crude oil washing certified by LR
SBT (LR)	Segregated ballast tanks certified by LR.

2.9.2 When a notation is assigned in accordance with *Pt 1, Ch 2, 2.8 Class notation (Verification Schemes)*, a supplementary character will also be added to indicate the applicable National Administration, e.g. Norwegian Verification **(N)**, United Kingdom Verification **(UK)**.

2.9.3 Where an approved loading instrument is provided as an Owner's requirement, a descriptive note **LI** may be entered on the Class Direct website.

2.9.4 Where LR's ShipRight procedures for the following have been applied on a voluntary basis to surface type units, a descriptive note will, at the Owner's request, be entered on the Class Direct website, see also ShipRight Procedures Overview and *Pt 1, Ch 2 Classification Regulations* of the Rules for Ships:

ES	Enhanced Scantlings
SEA (HSS-n)	Ship Event Analysis (Hull Surveillance Systems)
SERS	Ship Emergency Response Service
SCM	Screwshaft Condition Monitoring
MCM	Machinery Condition Monitoring
MCBM	Machinery Condition Based Maintenance
MPMS	Machinery Planned Maintenance Scheme
RCM	Reliability Centred Maintenance
BWMP	Ballast Water Management Plan
ThCM	Thruster Condition Monitoring

A table summarising the descriptive notes given in this part of the Rules and other notes listed elsewhere in the Rules can be found in *Appendix 2 Descriptions*.

2.9.5 Where evidence exists that supporting calculations have been performed in accordance with hull structural finite element and fatigue analysis procedures of a recognised Classification Society, then, on application from Owners, the descriptive note **ShipRight (E)** may be entered on the Class Direct website.

2.9.6 Where an Owner elects to undertake hull Special Survey in accordance with the requirements of *Pt 1, Ch 3, 7 Special Survey - Oil tankers (including ore/oil ships and ore/bulk/oil ships) - Hull requirements* of the Rules for Ships, the descriptive note **ESP** may be entered on the Class Direct website.

■ *Section 3* Surveys — General

3.1 Statutory surveys

3.1.1 The Classification Committee will act, when authorised on behalf of National Administrations, in respect of national and international statutory safety and other requirements for offshore units.

3.1.2 The Classification Committee will also act, when authorised, in respect of national safety, coastal state regulations relating to offshore units used for the exploration and exploitation of hydrocarbons.

3.2 New construction surveys

3.2.1 When it is intended to build a unit for classification with LR, constructional plans and all necessary particulars relevant to the hull/structure, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of LR before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be documented and submitted for approval.

3.2.2 Where the proposed construction of any part of the hull/structure or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application

involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be assigned.

3.2.3 The materials used in the construction of the hull/structure and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of the Rules for Materials. The steel is to be manufactured by an approved process at an approved works. Alternatively, tests will be required to demonstrate the suitability of the steel.

3.2.4 Materials used in the construction of drilling and process plant are to comply with 3.2.3 and with the requirements of Part 3, see also 3.2.12.

3.2.5 New units intended for classification are to be built under LR's Special Survey. From the commencement of work until the completion of the unit, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.6 For compliance with 3.2.5, LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems. The minimum requirements for the approval of any such proposed Quality Assurance methods are laid down in *Pt 4, Ch 11 Quality Assurance Scheme (Hull)*.

3.2.7 Copies of approved plans (showing the unit as built), essential certificates and records, the Operations Manual and loading and other instruction manuals are to be readily available for use when required by the attending Surveyors.

3.2.8 When the machinery and drilling/process plant of a unit are constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.9 When remote and/or automatic control equipment, alarms and safeguards are fitted to the machinery and drilling/ process plant, and riser systems the equipment is to be arranged, installed and tested in accordance with LR's Rules and Regulations.

3.2.10 The date of completion of the Special Survey during construction of units built under LR's inspection will normally be taken as the date of build to be entered on the *Class Direct* website. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated on the *Class Direct* website.

3.2.11 When a unit, upon completion, is not immediately commissioned but is laid up for a period, the Classification Committee, upon application by the Owner prior to the unit being commissioned, will direct an examination to be made on site or in dry dock by the Surveyors. If, as a result of such survey, the structure, equipment and machinery are reported in all respects in accordance with applicable Rule requirements, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.2.12 Where classification is to be based on a formal safety case approach, see*Pt 1, Ch 2, 1.4 General* , special consideration will be given by LR to the use of materials in accordance with internationally recognised Codes and Standards, see 3.2.3.

3.3 Existing units

3.3.1 **Classification of units not built under survey**. The requirements of the Classification Committee for the classification of units which have not been built under LR's Survey are indicated in *Pt 1, Ch 3, 19 Classification of units not built under survey*. Special consideration will be given to units transferring class to LR from another recognised Classification Society.

3.3.2 **Reclassification**. When reclassification or class reinstatement is desired for a unit for which the class previously assigned by LR has been withdrawn or suspended, the Classification Committee will direct that a survey appropriate to the age of the unit and the circumstances of the case be carried out by the Surveyors. If, at such survey, the unit is found or placed in a condition in accordance with the requirements of the Rules and Regulations, the Classification Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 The Classification Committee reserves the right to decline an application for classification or reclassification where the prior history of condition of the unit indicates this to be appropriate.

3.3.4 **Unscheduled surveys**. Where the Classification Committee has concern about the condition of the unit and/or the equipment, an unscheduled survey may be required at any time to determine the actual condition.

3.4 Damages, repairs and alterations

3.4.1 All repairs to hull/structure, equipment, machinery and drilling/process plant which may be required in order that a unit may retain its class, see 1.4.6, are to be carried out to the satisfaction of the Surveyors. Alternatively, the Classification Committee may agree, in exceptional cases, that quality control can be enforced by the Owner or repairer, on site, in which case the repairs are to be surveyed by the Surveyors at the earliest opportunity thereafter.

3.4.2 When, at any survey, the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Classification Committee by the Surveyors.

3.4.3 When, at any survey, it is found that any damage, defect or breakdown, see*Pt 1, Ch 2, 1.4 General*, is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Classification Committee for consideration.

3.4.4 If a unit which is classed with LR is damaged to such an extent as to necessitate towage outside port limits whilst in a damaged condition to a suitable repair facility, it shall be the Owner's responsibility to notify LR at the first practicable opportunity.

3.4.5 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull/ structure, equipment, machinery or drilling/process plant are to be submitted for approval, and such alterations are to be carried out to the satisfaction of the Surveyors.

3.5 Existing installations – Periodical Surveys

3.5.1 Annual Surveys are to be held on all units within three months, before or after each anniversary of the completion, commissioning or Special Survey, in accordance with the requirements given in Chapter 3. The date of the last Annual Survey will be recorded on the *Class Direct* website.

3.5.2 Intermediate Surveys are to be held on all units instead of the second or third Annual Survey after completion, commissioning or Special Survey, in accordance with the requirements given in *Pt 1, Ch 3, 3 Intermediate Surveys – Hull and machinery requirements*. The Intermediate Survey may be commenced at the second Annual Survey and progressed with completion at the third Annual Survey. The date of the last Intermediate Survey will be recorded on the *Class Direct* website. The concurrent crediting of items towards both Intermediate Survey and Special Survey is not permitted.

3.5.3 The Owner should notify LR whenever a unit can be examined in dry dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. The Classification Committee will accept In-Water Surveys in lieu of Docking Surveys on units assigned an **OIWS** (In-Water Survey) notation, see*Pt 1, Ch 3, 4.3 In-water surveys* .

3.5.4 One of the two Docking Surveys or In-Water Surveys in lieu of Docking Surveys required in each five-year period is to coincide with the Special Survey, see 3.5.3. Consideration may be given in exceptional circumstances to an extension of this interval not exceeding three months beyond the due date. In this context 'exceptional circumstances' means unavailability of dry-docking facilities, repair facilities, essential materials, equipment or spare parts or delays incurred by action taken to avoid severe weather conditions.

3.5.5 The date of the last examination in dry dock or In-Water Survey will be recorded on the Class Direct website.

3.5.6 Attention is to be given to all relevant statutory requirements of the National Authority/Coastal State Authority in the country in which the unit is registered and/or is to operate.

3.5.7 When LR is to carry out verification on behalf of a National Authority, classification surveys required by the Rules, will, where practicable, be combined, and aligned, with the surveys required by the National Authority.

3.5.8 All units classed with LR are also to be subjected to Special Surveys in accordance with the requirements given in Ch 3,5. These surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded on the Class Direct website, and thereafter five years from the date recorded for the previous Special Surveys. See also 3.2.10. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed, the next period of hull classification will start from the date of the Special Survey before the extension was granted. A definition of 'exceptional circumstances' is given in 3.5.4.

3.5.9 Special surveys may be commenced at the fourth Annual Survey after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey. As part of

the preparation for the Special Survey, the thickness determination, where applicable, may be dealt with in connection with the fourth Annual Survey.

3.5.10 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, if such work is to be credited towards the Special Survey. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary. In cases where the unit has been laid up or has been out of service because of a major repair or modification and the Owner elects to only carry out the overdue surveys, the existing Special Survey date will be maintained. If the Owner elects to carry out the next due Special Survey, the new record of the Special Survey will be the final date of survey.

3.5.11 At the request of an Owner, it may be agreed that the Special Survey of the hull/structure be carried out on the Continuous Survey basis, where all compartments of the hull are to be opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular Special Survey of the hull/structure must be completed by the end of the five-year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements* and *Pt 1, Ch 3, 3.2 Intermediate Surveys*, the intervals for inspection will require to be specially agreed. Units which have satisfactorily completed the cycle will have the date of completion entered on the Class Direct website, which will not be later than five years from the last assigned date of complete Survey of the hull/structure. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Classification Committee.

3.5.12 The Owner is to prepare a planned survey programme for the inspection of the hull/structure after each Special Survey, before the next Annual Survey is due. The survey programme is to cover the requirements for Annual Surveys, Intermediate Surveys, Special Periodical Surveys, Special Continuous Surveys, Docking Surveys and In-Water Surveys in lieu of Docking Surveys and is to be submitted to LR for review. A copy is to be kept on board and made available to the Surveyor. The survey programme should include plans, etc., for identifying the areas to be surveyed, the extent of hull cleaning, locations for non-destructive examination (including NDE methods), nomenclature, and methods for the recording of any damage or deterioration found. The planned survey programme, as agreed by LR, will be subject to revision if it is found to be necessary at subsequent surveys, or when required by the Surveyor. See Ch 3,1.6.

3.5.13 The requirements for survey and the schedule of surveyable items may be amended when any variation in service duties, usage or change in type notation is proposed, by agreement between the Owner and the Classification Committee.

3.5.14 Machinery is to be subjected to the surveys detailed in *Pt 1, Ch 3, 6 Machinery Surveys – General requirements*.

3.5.15 Drilling/process plant, safety and communication systems and hazardous areas are to be subjected to the surveys detailed in *Pt 1, Ch 3, 13 Drilling plant facility*, *Pt 1, Ch 3, 14 Process plant facility* and *Pt 1, Ch 3, 16 Safety and communication systems and hazardous areas*.

3.5.16 Complete Surveys of machinery and drilling/ process plant become due at five-yearly intervals, the first one from the date of build or date of first classification as recorded on the Class Direct website and thereafter five years from the date recorded in the Survey records for the previous complete survey. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before the extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Classification Committee. On satisfactory completion of a survey, an appropriate entry will be made in the Survey Records. Where the survey is completed more than three months before the due date, the new date recorded will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary.

3.5.17 Upon application by an Owner, the Classification Committee may agree to the extension of the survey requirements for main engines which, by the nature of the unit's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 3.5.16.

3.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.19 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the machinery and/or drilling/process plant may be carried out on the Continuous Survey basis, the various items of machinery and plant are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery and plant is to be examined each year. A record indicating the date of satisfactory completion of the Continuous Survey cycle will be made in the Survey Records.

3.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to the Surveyor's satisfaction.

3.5.21 Upon application by an Owner, the Classification Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the unit followed by a limited confirmatory survey carried out later by an Exclusive Surveyor. Particulars of this arrangement may be obtained from LR. Where an approved planned maintenance scheme is in operation, the confirmatory surveys may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from LR.

3.5.22 Where condition monitoring equipment is fitted, the Classification Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

3.5.23 The survey of boilers and other pressure vessels and the examination of steam pipes and Screwshaft Surveys are to be carried out as stated in *Pt 1, Ch 3, 10 Boilers*.

3.5.24 The survey of pressure vessels for process and drilling plant is to be carried out as stated in *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

3.5.25 Where any inert gas system is fitted for the protection of storage tanks on board a unit intended for the storage of crude oil in bulk, the system is to be surveyed annually in accordance with the requirements of *Pt 1, Ch 3, 2.6 Inert gas systems*. In addition, on units to which an **IGS** notation has been assigned, a Special Survey of the inert gas plant is to be carried out at intervals not exceeding five years, in accordance with the requirements of *Pt 1, Ch 3, 18 Inert gas systems*.

3.5.26 Where the unit is fitted with a dynamic positioning system, the system is to be examined and tested annually, in accordance with the requirements of*Pt 1, Ch 3, 2.3 Machinery*. In addition, a Special Survey is to be carried out at intervals not exceeding five years, in accordance with*Pt 1, Ch 3, 6.2 Complete Surveys* .

3.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the unit may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey due date and an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date. In order to reactivate a unit from lay up and return it into service, the Owner must make an application to the Classification Committee. They will consider the application and decide on the extent of surveys to be carried out, based on surveys overdue and the duration of lay up.

3.6 Surveys for novel/complex systems

3.6.1 Where novel/complex machinery and equipment have been accepted by LR and for which existing survey requirements are not considered to be suitable and sufficient then appropriate survey requirements are to be derived as part of the design approval process. In deriving these requirements LR will consider, but not be limited to, the following:

(a) Plan appraisal submissions;
(b) Risk based analysis documentation where required by the Rules;
(c) Equipment manufacturer recommendations;
(d) Relevant recognised national or international standards.

3.7 Certificates

3.7.1 When the required reports, on completion of the survey of new or existing units which have been submitted for classification, the required reports have been received from the Surveyors and classification has been agreed by the Classification Executive, a certificate of Classification may be issued by an authorised Surveyor. After approval by the Classification Committee, a certificate of First Entry of Classification, signed by LR's Chairman or the Chairman of the Classification Committee, will be issued to Builders or Owners.

3.7.2 A Certificate of Class valid for five years subject to endorsement for Annual and Intermediate Surveys will also be issued to the Owners.

3.7.3 LR Surveyors are permitted to issue provisional (interim) certificates to enable an offshore unit classed with LR to proceed on its voyage or to continue in service, provided that, in their opinion, the unit is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Classification Committee.

3.7.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and the provisional (interim) certificates.

3.7.5 Under no circumstances is the extension of validity of a class certificate to be granted beyond the due date of a Periodical Survey without the essential inspection (including NDE) having been completed for all prescribed parts of the primary structure.

3.8 Notice of surveys

3.8.1 It is the responsibility of the Owner to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Classification Committee. Information is available to Owners on the *Class Direct* website.

3.8.2 LR will give timely notice to an Owner about forthcoming surveys. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the *Class Direct* website.

3.9 Temporary suspension of class

3.9.1 When an Owner intends to move a classed unit, whether self-propelled or not, to a new operating area and, due to the unit's significant design criteria, it is not suitable for exposed sea passages outside its normal operating area, the certificate of class will automatically be suspended during sea voyages. Class will be reinstated provided that the environmental criteria for the new area do not exceed the design criteria, and that an inspection by LR Surveyors when the unit arrives in the new area establishes that the hull/structure has suffered no damage in transit and remains in an efficient condition.

3.9.2 Self-propelled units which are disconnectable in order to avoid severe storm conditions or hazards will automatically remain in class and the certificate of class will be endorsed accordingly provided the environmental criteria for the proposed sea voyages do not exceed the design criteria. Reinstallation is to be subject to inspection by LR Surveyors.

3.9.3 When it is contemplated to tow a unit to an area which is outside the normal operating area of the unit, the towing arrangements are to be approved and certified by a competent authority for the particular voyage.

3.9.4 Although it is not generally a condition of class that the assessment of a unit as being fit for a particular sea passage should be undertaken by LR, when requested, LR is prepared to advise on the measures to be adopted for such a voyage, to supervise their execution and to issue the appropriate certificates.

3.9.5 All units will remain in class during location moves (i.e. moves within the same operational area) provided that:

(a) approved procedures stated in the unit's Operations Manual are adhered to;
(b) the towing arrangements and equipment on nonpropelled units are to comply with *Pt 4, Ch 9, 2 Towing arrangements*; and
(c) reports of any inspections of critical areas carried out during such moves are retained for review, where appropriate, by the Surveyors.

3.10 Withdrawal/suspension of class

3.10.1 When the class of a unit, for which the Regulations with regard to surveys on hull/structure, equipment and machinery have been complied with, is withdrawn by the Classification Committee as a result of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.10.2 When the Regulations with regard to survey on the hull/structure, equipment, machinery or the drilling/process plant have not been complied with and the unit thereby is not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned.

3.10.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey is not completed within three months of the due date of the survey.

3.10.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed, see 3.5.8, or is not under attendance by the Surveyors with a view to completion prior to resuming operations.

3.10.5 When, in accordance with 3.4.3 of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the unit's class may be suspended if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.10.6 If it is found, from the reported condition of the hull or equipment or machinery or the drilling/process plant of a unit that an Owner has failed to comply with *Pt 1, Ch 2, 1 Conditions for classification*,*Pt 1, Ch 2, 3.4 Damages, repairs and alterations*, the class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation assigned. If it is considered that an Owner's failure to comply with these requirements is sufficiently serious, the suspension or withdrawal of class may be extended to include other units controlled by the same Owner, at the discretion of the Classification Committee.

3.10.7 If the Classification Committee is satisfied that a unit has been operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous than, or in areas other than, those agreed by the Classification Committee, the class will be withdrawn or suspended in relation to those operations.

3.10.8 If the Classification Committee is satisfied that a unit proceeded to sea with less freeboard than that approved by the Classification Committee, or that the freeboard marks are placed higher on the sides of the unit than the position assigned or approved by the Classification Committee, or, in cases where units do not have freeboards assigned, the draught is greater than that approved by the Classification Committee, the class of the unit will be withdrawn or suspended in relation to the above voyages.

3.10.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group. In cases where class has been suspended by the Classification Committee and it becomes apparent that the Owners are no longer interested in retaining LR's Class, it will be withdrawn.

3.10.10 When a unit is intended for a demolition voyage with any Periodical Survey overdue, the unit's class suspension may be held in abeyance and consideration may be given to allow the unit to proceed on a single direct ballast voyage from the lay up or final discharge port to the demolition yard, provided the attending Surveyor finds the unit in a satisfactory condition to proceed for the intended voyage, at the discretion of the Classification Committee.

3.10.11 When a unit is intended for a single voyage from 'laid-up' position to repair yard with any Periodical Survey overdue, the unit's class suspension may be held in abeyance and consideration may be given to allow the unit to proceed on a single direct ballast voyage from the site of lay up to the repair yard, upon agreement with the Flag Administration, at the discretion of the Classification Committee. This is provided the unit is found in a satisfactory condition by surveys, the extent of which are to be based on surveys overdue and duration of lay-up.

3.10.12 For reclassification and reinstatement of class, see *Pt 1, Ch 2, 3.3 Existing units*.

3.11 Force Majeure

3.11.1 If due to circumstances reasonably beyond the Owner's or LR's control (limited to such cases as damage to the offshore unit or structure, unforeseen inability of LR to attend the offshore unit due to the governmental restrictions on right of access or movement of personnel, unforeseeable delays in port due to unusually lengthy periods of severe weather, strikes, civil strife, acts of war, or other cases of force majeure) the unit is not in a port where the overdue surveys can be completed at the expiry of the periods allowed, the Classification Committee may allow the unit to sail, in class, directly to an agreed facility and, if necessary, then, in ballast, to an agreed facility at which the survey will be completed, provided that LR:

(a) Examines the unit's records; and
(b) Carries out the due and/or overdue surveys and examination of recommendations at the first port of call when there is an unforeseen inability of LR to attend the unit in the present port, and
(c) Has satisfied itself that the unit is in a condition to sail for one trip to a facility and subsequent ballast voyage to a repair facility if necessary. (Where there is unforeseen inability of LR to attend the unit or structure in the present port, the master is to confirm that the unit is in condition to sail to the nearest port of call.)

3.12 Appeal against Surveyor's recommendations

3.12.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Classification Committee, who may direct a Special Examination to be held.

3.13 Ownership details

3.13.1 It is the responsibility of the Owner to inform a member of the LR Group in writing of any change to its contact details and, in the event of a unit sale, to supply details of the new Owners. If the new Owner of a unit cannot be properly identified nor contact details established, then the class of that unit will be specially considered by the Classification Committee. It is the responsibility of the new Owner to inform a member of the LR Group in writing of their contact details and that they are now responsible for the unit. If they fail to do so, the class of that unit will be specially considered by the Classification Committee.

3.14 Conversion surveys

3.14.1 The requirements in 3.1 are to be complied with.

3.14.2 A Special Survey as required for units of 20 years of age is to be completed at the time of conversion, see *Pt 1, Ch 3, 5 Special Survey – Hull requirements*.

3.14.3 All critical locations in the existing structure which may be prone to fatigue cracking are to be examined by MPI or other suitable NDE methods at the time of conversion, see*Pt 10, Ch 1, 6.3 Fatigue analysis*.

3.15 Life extension

3.15.1 A unit may remain in Class after the end of the design life of the unit, provided a life extension programme is approved and the appropriate surveys completed to the satisfaction of LR.

3.15.2 The life extension programme is to be submitted to LR for approval.

■ *Section 4*
Third party audits and assessments

4.1 Audit of surveys

4.1.1 The surveys required by the Regulations may be subject to audit or assessment in accordance with the requirements of the relevant third party audit regimes, e.g., for mobile offshore units the requirements of the International Association of Classification Societies and the European Maritime Safety Agency.

■ *Section 1*
General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. Except as amended at the discretion of the Classification Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.
(b) Intermediate Surveys as required by *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.
(c) Docking Surveys and In-water Surveys as required by *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.
(d) Special Surveys at five-yearly intervals, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*, for alternative arrangements, see also*Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.

(e) Complete Surveys of machinery at five-yearly intervals, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys* and 3.5.19. The requirements of 1.1.1(a) to (c) are also to be complied with.

1.1.3 **Ship units and other surface type units:** for units with crude oil bulk storage tanks, the additional requirements of *Pt 1, Ch 3 Periodical Survey Regulations* of the Rules for Ships are to be complied with, as applicable.

1.1.4 For the frequency of surveys of boilers and other pressure vessels, steam pipes, screwshafts, tube shafts, propellers and thrusters, see *Pt 1, Ch 3, 10 Boilers*, see also 1.1.5.

1.1.5 For the frequency of surveys of pressure vessels for process and drilling plant, see *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

1.1.6 For the frequency of surveys of process plant, drilling plant and riser systems, see *Pt 1, Ch 3, 13 Drilling plant facility*.

1.1.7 For the frequency of surveys of inert gas systems, see *Pt 1, Ch 3, 18 Inert gas systems*.

1.1.8 For the frequency of surveys of safety and communication systems and hazardous areas, see *Pt 1, Ch 3, 16 Safety and communication systems and hazardous areas*.

1.2 Surveys for damage or alterations

1.2.1 At any time when a unit is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, insulation or fittings, is removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull, machinery, or drilling/process plant and the applicable statutory requirements, whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any unit, LR reserves the right to perform unscheduled surveys of the hull structure or machinery of other similar units classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention Certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member, when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **Unit types** are defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations* and *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

1.5.2 **Critical areas** are locations vulnerable to substantial corrosion, buckling and/or fatigue cracking.

1.5.3 A **ballast tank** is a tank which is used solely for salt-water ballast. A space which is used for both the storage of liquids and salt-water ballast will be treated as a salt-water ballast tank when substantial corrosion has been found in that space.

1.5.4 **Preload Tank** is a tank within the hull of a self-elevating unit. These tanks are periodically filled with salt water ballast and used to preload the footings of the unit prior to commencing drilling operations. Preload Tanks are considered equivalent to Ballast Tanks.

1.5.5 **Spaces** are separate compartments such as tanks, pump-rooms, cofferdams and void spaces bounding cargo holds, decks and outer hull.

1.5.6 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure and to determine the extent of additional Close-up Surveys as necessary.

1.5.7 A **Close-up Survey** is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e., normally within reach of hand.

1.5.8 **Representative spaces** are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces, account should be taken of the service and repair history on board and identifiable Critical Structural Areas.

1.5.9 **Enclosed space**. An enclosed space is any place of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions. Examples include, but are not limited to: boilers, pressure vessels, cargo spaces (cargo holds or cargo tanks), cargo space stairways, ballast tanks, double bottoms, double hull spaces, fuel oil tanks, lube oil tanks, sewage-tanks, pump-rooms, compressor rooms, cofferdams, void spaces, duct keels, inter-barrier spaces, engine crankcases, excavations and pits.

1.5.10 **Substantial corrosion** is wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.11 A **protective coating** is normally a full hard protective coating. This is usually to be an epoxy coating or equivalent.

1.5.12 An **independent double bottom tank** is a double bottom tank which is separate from topside tanks, side tanks or deep tanks.

1.5.13 **NDE** is Non-Destructive Examination, consisting of visual examination and Non-Destructive Testing (NDT).

1.5.14 **Coating condition** is defined as follows:

GOOD. Condition with only minor spot rusting.

FAIR. Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for poor condition.

POOR. Condition with general breakdown of coating over 20 per cent of areas and hard scale at 10 per cent or more of area under consideration.

1.5.15 A **prompt and thorough repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, thereby removing the need for the imposition of any associated condition of class or recommendation.

1.5.16 **Critical structural areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject unit or from similar units, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit.

1.5.17 **Specially considered** (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

1.5.18 **Excessive Diminution (or excessive corrosion)** is an extent of corrosion beyond allowable limits

1.5.19 **Suspect Area** are locations showing Substantial Corrosion and/or are considered by the Surveyor to be prone to rapid wastage.

1.5.20 **A natural gas fuel installation** comprises the following; fuel bunkering, fuel storage, fuel processing and fuel delivery to gas fuelled consumers. The scope of the natural gas fuel installation extends from the bunker manifold to the natural gas fuelled consumer and includes any re-liquefaction plant and compressors that are fitted to manage boil off.

1.6 Planned survey programme

1.6.1 A planned survey programme is to be developed by the Owner and submitted to LR for approval in advance of the first survey, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. The programme should include guidance for control and recording of all relevant aspects of the inspection and replacement philosophy. In particular, the programme is to include and address the following:

(a) the overall design configuration;
(b) field life potential;
(c) appropriate regulatory requirements;
(d) main hull structural arrangement plans;
(e) details of planning, identification and preparation procedures;
(f) areas to be surveyed and extent of hull cleaning;
(g) inspection and testing schedules for all relevant compartments, equipment and systems;

(h) inspection methods and procedures;
(i) extent, frequency and circumstances for application of NDE;
(j) locations for non-destructive testing;
(k) schedule for overall survey, close-up survey and thickness measurement;
(l) condition of coatings and corrosion prevention systems;
(m) methods for reporting and recording of damage or deterioration found and remedial measures;
(n) allowable wastage limits (corrosion margins and wear allowances) for each part of the structure and mooring system.

1.6.2 Particular attention is to be paid to critical areas and also to areas of suspected damage or deterioration and to repaired areas. Surveys are to take into account locations highlighted by service experience and the design assessment.

1.6.3 A planned survey programme for positional mooring systems is to be developed by the Owner and submitted to LR for approval, see*Pt 1, Ch 3, 2.2 Structure and equipment*.

1.6.4 A planned survey programme for units assigned a **PPF** notation and/or a **DRILL** notation is to be developed by the Owner and submitted to LR for approval, see *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements*.

1.6.5 Planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

1.6.6 A planned survey programme for installations with riser systems assigned a **PRS** notation is to be developed by the Owner and submitted to LR for approval, see *Pt 1, Ch 3, 15 Riser systems*.

1.7 Preparation for survey and means of access

1.7.1 In order to enable the attending Surveyor(s) to carry out the survey, provision for proper and safe access is to be agreed between the Owner and LR. Tanks and spaces are to be safe for access, gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.7.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned, including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc., to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the protective coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.7.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.7.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

1.7.5 Survey at an offshore location or anchorage may be undertaken when the Surveyor is fully satisfied with the access, egress and communications arrangements provided and that the personnel on board are competent in the application and use of all relevant safety and communications equipment and procedures.

1.7.6 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.7.7 **For natural gas fuel installations** *see also Pt 1, Ch 3, 21.1 General*.

1.8 Thickness measurement at survey

1.8.1 This Section is applicable to the thickness measurement of the structure where required by*Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements*.

1.8.2 Prior to the commencement of the Intermediate Survey and Special Survey, a meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company representative and the Master of the unit or an appropriately qualified representative appointed by the Master or Owner, so as to ensure the safe and efficient conduct of the survey and thickness measurements to be carried out. See also*Pt 1, Ch 3, 1.6 Planned survey programme*.

1.8.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a firm approved in accordance with LR's Approval for Thickness Measurement of Hull Structure.

1.8.4 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be re-coated as necessary.

1.8.5 Thickness measurements are to be taken in the forward and aft areas of all plates. Where plates cross ballast/cargo tank boundaries, separate measurements for the area of plating in way of each type of tank are to be reported. In all cases, the measurements are to represent the average of multiple measurements taken on each plate and/or stiffener. Where measured plates are renewed, the thickness of adjacent plates in the same strake is to be reported.

1.8.6 Thickness measurement of units with storage tanks for liquefied gases or chemicals will be specially considered.

1.8.7 The extent and frequency of thickness measurement on structure with substantial corrosion will be specially considered. The survey will not be considered complete until all required thickness measurements have been carried out.

1.8.8 Thickness measurements are to be witnessed by the Surveyor to the extent necessary to control the process. This also applies to thickness measurements carried out while the unit is at an offshore location.

1.8.9 Thickness measurements may be carried out within the 12 months prior to the due date of the Special Survey.

1.8.10 Where it is required as part of the survey to carry out thickness measurements for the structural areas subject to Close-up Survey, these measurements are to be carried out simultaneously with the Close-up Survey.

1.8.11 The Surveyor may extend the scope of thickness measurement if deemed necessary.

1.8.12 Thickness determination by drilling structural members is not permitted.

1.8.13 In all cases, the extent of the thickness measurements is to be sufficient to represent the actual average condition.

1.8.14 A report is to be prepared by the approved firm carrying out the thickness measurements. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the Operator.

1.8.15 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an authorising Surveyor.

1.9 Repairs

1.9.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the structural, watertight or weathertight integrity of the unit, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the unit to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.9.2 Where it is proposed to defer repairs, a defect criticality assessment is to be submitted for approval, demonstrating the effectiveness of any mitigation measures (*inter alia* monitoring, loading restrictions) and continued suitability until repaired.

1.10 Steel renewal criteria

1.10.1 This Section defines the in-service steel renewal criteria for the net scantlings design basis described in *Pt 4, Ch 3, 7 Corrosion additions*. The net thickness of a structural element is that required for structural strength and is separate from the thickness added to address corrosion in-service.

1.10.2 The plans to be supplied on board the unit are to include both the as-built and renewal thicknesses. Any Owner's extra thickness is also to be clearly indicated on the drawings. The as-built Midship Section plan provided by the Builder and carried on board the unit is to include a Table showing the minimum allowable hull girder sectional properties for the mid-tank transverse section in all cargo tanks.

1.10.3 Re-examination and additional thickness measurements are required annually where the coating condition is POOR, as defined in *Pt 1, Ch 3, 1.5 Definitions 1.5.12*. Where the design basis considers uncoated surfaces, or planned degradation to coating effectiveness, examination periods can be specially considered provided that degradation can be demonstrated to be not in excess of that originally anticipated.

1.10.4 Steel renewal is to be carried out when the measured thickness is less than:

$$t = t_{net} + N_t\,(t_{c1} + t_{c2}) \text{ mm, rounded up to the nearest 0,25 mm}$$

For tank bottom plating:

$$t = 6 + N_t\,(20t_{c1} + t_{c2}) \text{ mm, rounded up to the nearest 0,25 mm}$$

where

t_{net} = required net thickness

N_t = number of years between surveys (not to be taken as greater than 5 years or less than 1 year)

t_{c1} and t_{c2} are the corrosion rates for each side of the structural member.

t_{c1} is the value for the side of the structural member within the tank.

1.10.5 General corrosion is defined as areas where general uniform reduction of material thickness is found over an extensive area.

1.10.6 Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area. The pitting intensity is defined in *Figure 3.1.1 Pitting intensity*.

1.10.7 Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in *Figure 3.1.2 Edge corrosion*.

1.10.8 Groove corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in *Figure 3.1.3 Groove corrosion*.

1.10.9 For local structure when general corrosion has occurred, steel renewal is required where the measured thickness is less than the renewal thickness:

$$t = t_{net} + t_{c1} + t_{c2} \text{ mm, rounded up to the nearest 0,25 mm}$$

where

t_{net} = required net thickness

t_{c1} and t_{c2} are defined in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*.

For inspection intervals greater than one year, this criterion assumes that a localised reduction in the net thickness can be tolerated.

1.10.10 For plates with pitting intensity less than 20 per cent, *see Figure 3.1.1 Pitting intensity*, steel renewal is required where the measured thickness of any one measurement is less than: 0,7 (as-built thickness – Owner's extra); or 1 mm less than the renewal thickness. For all levels of pitting intensity, steel renewal is also required where the average thickness across any cross-section in the plating is less than the renewal criteria for general corrosion given in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*.

1.10.11 Where the overall height or breadth of edge corrosion is less than 25 per cent of the stiffener height or flange breadth, h_{stf} or b_{stf} in *Figure 3.1.2 Edge corrosion*, steel renewal is required where the measured thickness is less than:0,7 (as-built thickness – Owner's extra); or1 mm less than the renewal thickness. Steel renewal is also required where the average thickness across the breadth or height of the stiffener is less than the renewal criteria for general corrosion given in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*.Where edge corrosion extends over more than 25 per cent of the height or breadth of the stiffener, local renewal criteria for general corrosion as defined in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3* is to be used.

1.10.12 Plate edges at openings for manholes, lightening holes, etc. may be below the minimum thickness given in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*, provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*, from the opening edge is not more than 20 per cent of the smallest dimension of the opening and does not exceed 100 mm;

(b) rough or uneven edges may be cropped back, provided that the maximum dimension of the opening is not increased by more than 10 per cent.

1.10.13 For grooved areas, steel renewal is required where the measured thickness is less than:

0,75 (as-built thickness – Owner's extra);
0,5 mm less than the renewal thickness; or
less than 6 mm.

Members with areas of grooving greater than 15 per cent of the web height or 30 mm are to be assessed based on the criteria for general corrosion as defined in *Pt 1, Ch 3, 1.10 Steel renewal criteria 1.10.3*, using the average measured thickness across the plating/stiffener.

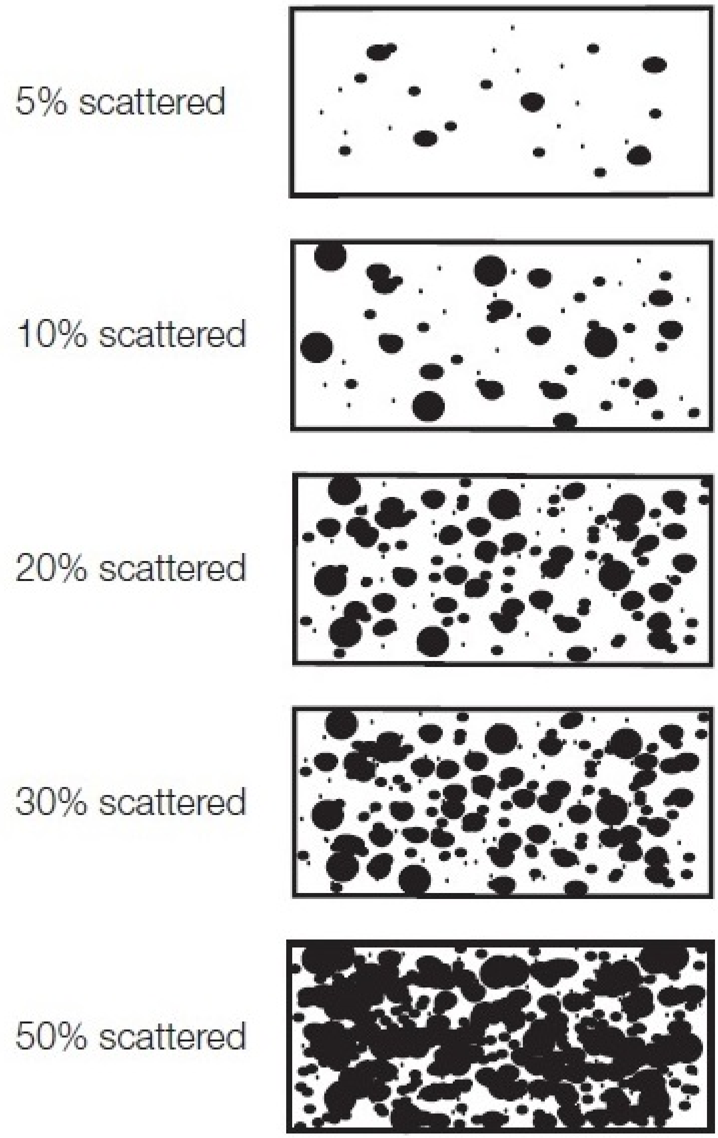


Figure 3.1.1 Pitting intensity

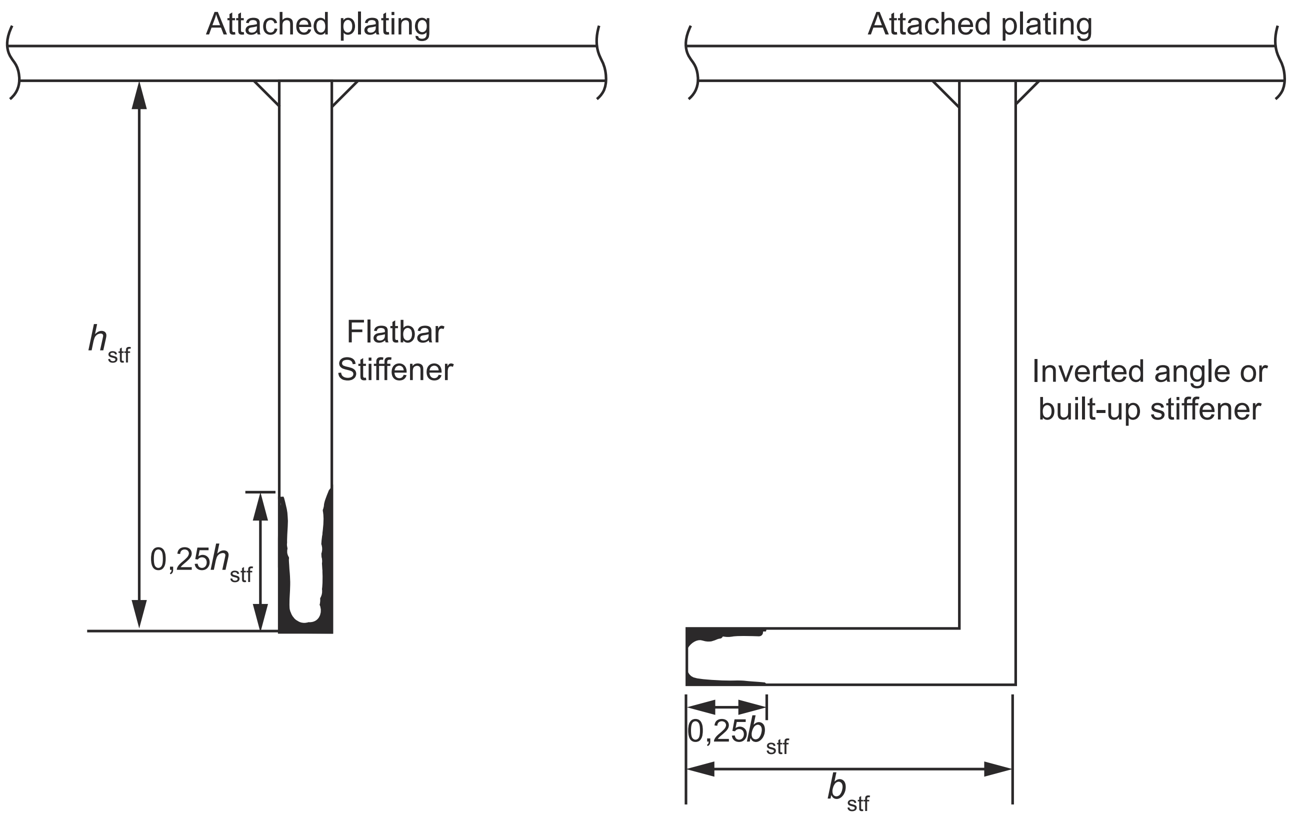


Figure 3.1.2 Edge corrosion

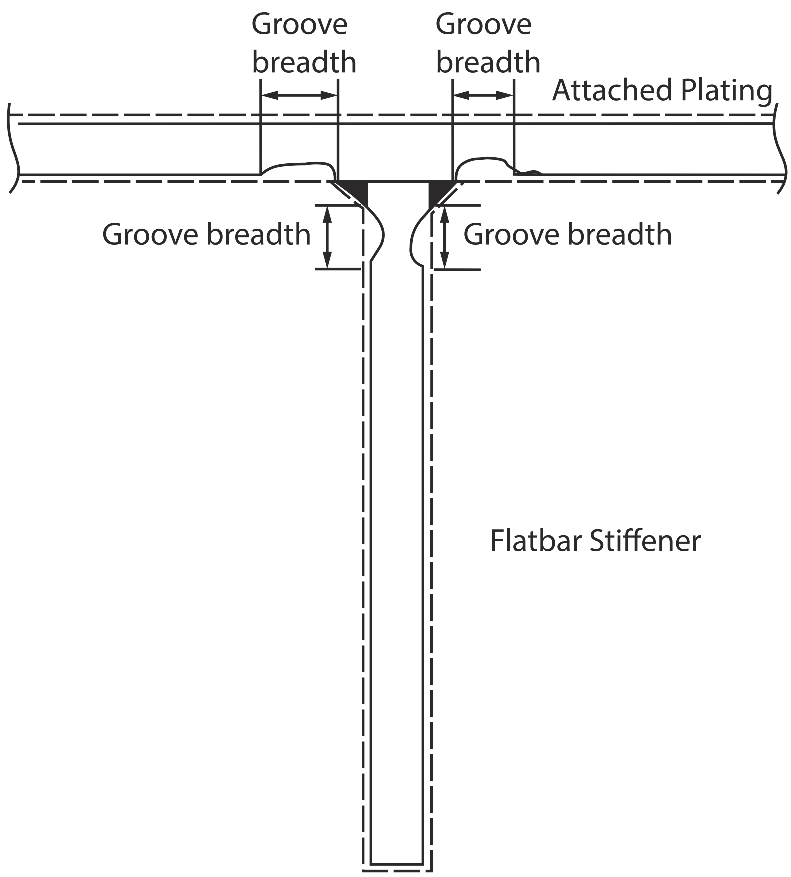


Figure 3.1.3 Groove corrosion

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with statutory annual or other relevant statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For ship units and other surface type units which are required by International Convention to comply with the International Safety Management Code (*ISM Code - International Management Code and Revised Guidelines on Implementation of the ISM Code*), the Surveyor is to review the overall effectiveness of the Code on board the unit. This is to be undertaken regardless of the organisation issuing the Safety Management Certificate (SMC).

2.1.4 For salt-water ballast tanks, other than independent double bottom tanks, where a protective coating is found to be in POOR condition, as defined in*Pt 1, Ch 3, 1.5 Definitions*, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

2.1.5 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in *Pt 1, Ch 3, 1.5 Definitions*, and it has not been repaired, where a soft or semi-hard coating has been applied or where a

protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

2.1.6 For **natural gas fuel installations** *see also Pt 1, Ch 3, 21.2 Survey Following Repair* to *Pt 1, Ch 3, 21.6 Annual Survey - Fuel Bunkering System*.

2.2 Structure and equipment

2.2.1 At each Annual Survey the exposed parts of the hull structure, deck, deck-houses, superstructures and structures attached to the deck, including supports to drilling/process plant, derrick substructures, crane pedestals and other supporting structures, accessible internal spaces and the applicable parts listed under unit types, as specified in 2.2.2 to 2.2.5, are to be generally examined and the Surveyor is to be satisfied as to their efficient condition.

2.2.2 **All unit types**. The Surveyor is to be satisfied regarding the efficient condition of:

- Hatchways, manholes and other openings in freeboard and superstructure decks or leading into buoyant spaces.
- Machinery casings and covers, companionways, and deck-houses protecting openings.
- Side scuttles and deadlights, and other openings in hull shell boundaries or in enclosed superstructures.
- Ventilators and air pipes together with flame screens, fiddley openings, skylights, flush deck scuttles and overboard discharges from enclosed spaces. In addition, the Surveyor is to examine externally all air pipe heads installed on exposed decks.
- Closing appliances for all the above, including check valves, hatch covers and doors, together with their respective securing devices, sills, coamings and supports.
- Watertight bulkheads, and end bulkheads of enclosed superstructures.
- Watertight doors and hatch covers in watertight boundaries, their indicators and alarms, to be examined and tested (locally and remotely), together with an examination of watertight boundary penetrations, so far as is practicable.
- Freeing ports together with bars, shutters and hinges.
- Windlasses and attachment of anchor racks and anchor cables.
- Protection of the crew, guard-rails, life-lines, gangways and deck-houses accommodating crew.
- The type, location and extent of corrosion control (i.e., coatings, cathodic protection systems, etc.), as well as its effectiveness, and repairs or renewals should be reported at each survey.

2.2.3 **Column-stabilised units and tension-leg units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components including NDE of critical areas, see also*Pt 1, Ch 3, 1.6 Planned survey programme* and *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. The Annual Survey is to include a complete bracing Close-up Survey, consisting of a detailed dry examination of all bracings and their structural connections to columns, pontoons and decks. The following critical regions are to be examined by approved methods of NDE:

(a) Primary bracing shell plating, including butts and seams and welding in way of the toes of both internal and external brackets (i.e., axial gusset or diaphragm plates and stiffener ends).
(b) Primary bracing shell plating and welding in way of changes of section, connections to main structure (e.g., columns, lower hulls, pontoons, decks, etc.) and intersections with other braces or node fabrications.
(c) All penetrations and attachments to primary bracings including drain, vent and access holes, hydrophone mountings, together with edge reinforcements, attachments for cathodic protection (both sacrificial anodes and impressed current systems), and guard-rail mountings, eye plates or lugs, etc.
(d) Diaphragm, bulkhead or deck plating and welding inside columns, pontoons or upper hull connection areas, in way of ends of primary bracings, local shear gussets between adjacent tube ends, and gussets, brackets of stiffeners forming a continuity of axial members from inside bracings. Also, column or deck plating and welded connections to bracings in way of internal diaphragm inside bracing.
(e) Column connections to lower hulls, pontoons and upper hull structure, including internal supporting structure.
(f) The structure in way of tether connections on tensionleg units.

It is important that an agreed procedure be established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, see also *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. Specific critical regions are to be examined by approved methods of NDE. Column structure and upper hull structure where accessible above the waterline are to be generally examined.

2.2.4 **Self-elevating units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components, including NDE of critical areas, see also*Pt 1, Ch 3, 1.6 Planned survey programme* and*Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. The Surveyor is to be satisfied regarding the efficient condition of:

- Jack-house structures and attachments to upper hull or platform.
- Locking system.
- Jacking or other elevating systems and leg guides, externally.
- Legs as accessible above the waterline.
- Plating and supporting structure in way of leg wells.
- Drilling derrick support structure.

It is important that an agreed procedure is established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, see also*Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. Specific critical regions to be examined by approved methods of NDE include the following:

(a) Leg guides and hull support structure.
(b) Leg well bulkheads below jacking tower or jack-house.
(c) Connections between jack-house structure and main deck and underdeck supporting structure.
(d) The jack-house roof above the jacking machinery (i.e., above the shock foundation) and in the vicinity of upper guide structure.
(e) General inspection of bracings, gussets, chord joints and racks of the legs. Inspection of tubular or similar type legs including pin holes.
(f) Leg connections to bottom mats or spud cans.
(g) Drilling derrick supporting structure.

2.2.5 **Ship units and other surface type units**. The requirements of *Pt 1, Ch 3, 2 Annual Surveys - Hull and machinery requirements* of the Rules for Ships are to be complied with, as applicable. The Surveyor is to be satisfied regarding the efficient condition of:

- The hull and deck structure around the drilling wells and moonpools and in the vicinity of any other structural changes in section, slots, steps, or openings in the deck or hull and the back-up structure in way of structural members or sponsons connecting the hull.

2.2.6 The Surveyor is to confirm that an approved Operations Manual and Construction Portfolio are available on board, see*Pt 3, Ch 1, 3 Operations manual*.

2.2.7 Where applicable, the following are to be examined where accessible:

- The hull and deck structure around turret openings and turret areas.
- Turret bearings and seals.
- Mooring arms and yokes.
- Mooring arm pivots and bearings.
- Process plant support stools and deck structure in way.
- Swivel stack support structure.
- Swivel stack bearing and seals.
- Mooring hawser line and mooring arm attachments to the hull structure.
- Mooring hawser to buoy.

2.2.8 The Surveyor is to confirm that, where required, an approved loading instrument, together with its operating instructions, is available on board, see *Pt 1, Ch 2, 1.4 General*. The operation of the loading instrument is to be verified in accordance with LR's certification procedure.

2.2.9 For disconnectable units with equipment in accordance with *Pt 4, Ch 9 Anchoring and Towing Equipment*, anchors, cables, windlasses and winches are to be examined so far as practicable.

2.2.10 For units fitted with positional mooring equipment in accordance with *Pt 3, Ch 10 Positional Mooring Systems*, an initial inspection is to be carried out following the installation of the positional mooring system, to ensure that the system has been properly installed, has not suffered damage and, through confirmation of agreed testing and maintenance procedures, that it continues to maintain the vessel in the defined safe envelope.

2.2.11 For positional mooring systems, a rota of component parts of the mooring system is to be examined at each Annual Survey. A periodic inspection program is to be developed by the Owners/Operators and submitted to LR for approval. Annual Surveys should be capable of determining as far as practicable the general condition of the mooring system, including cables, chains, fittings, fairleads, connections and equipment. The Surveyor is to be satisfied that all components and equipment remain in an acceptable condition. Particular attention is to be given to the following:

- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers (including underwater stopper if fitted).
- Cable or chain in way of the splash zone.
- Cable or chain anchor line tension alarms are regularly tested at agreed intervals.
- Cable or chain tensions are regularly logged to confirm that agreed tensions have not been exceeded.

2.2.12 The Surveyor is to be satisfied regarding the freeboard marks on the unit's side.

2.2.13 The Surveyor is to be satisfied at each Annual Survey that no material alterations have been made to the unit, its structural arrangements, mooring system, subdivision, superstructure, fittings, and closing appliances upon which the stability approval and load line assignment is based.

2.2.14 The requirements of *Pt 1, Ch 3, 3.2 Intermediate SurveysPt 1, Ch 3, 5.3 Examination and testing*, regarding the survey of water ballast spaces are also to be complied with, as applicable.

2.2.15 The Surveyor is to carry out an examination and thickness measurement of areas identified at the previous Special Survey or Intermediate Survey as having substantial corrosion. These extended thickness measurements are to be carried out before the survey is credited as completed see *Pt 1, Ch 3, 5 Special Survey – Hull requirements*.

2.2.16 The Survey requirements for sea bed-stabilised units will be specially considered, but the requirements for column-stabilised and self-elevating units are to be complied with as applicable.

2.2.17 Survey requirements for units used for the storage of liquefied gas or chemicals will be specially considered.

2.2.18 Accessible areas on mooring buoys and mooring towers are to be generally examined.

2.3 Machinery

2.3.1 The main propulsion, essential auxiliary and emergency generators, including safety arrangements, controls and foundations, are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

2.3.2 For units which are disconnectable in order to avoid hazards or extreme storm conditions, unless agreed otherwise with LR, the Surveyor is to examine and test in operation all main and auxiliary steering arrangements, including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements, where applicable. For laid-up machinery, see Section 20.

2.3.3 The Surveyor is to inspect generally the machinery and boiler spaces, with particular attention being given to the propulsion system, auxiliary machinery, and any potential fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are free from obstruction.

2.3.4 The means of communication between the navigating bridge and the machinery control positions are to be tested.

2.3.5 The bilge pumping systems for each watertight compartment, including bilge wells, extended spindles, selfclosing drain cocks, valves fitted with rod gearing or other remote operation, pumps and level alarms, where fitted, are to be examined and operated as far as practicable and all confirmed to be satisfactory. Any hand pumps provided are to be included.

2.3.6 Piping systems containing fuel oil, lubricating oil or other flammable liquids are to be generally examined and operated, as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding arrangements.

2.3.7 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the nonmetallic joint are below the deepest load waterline.

2.3.8 Boilers and other pressure vessels and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping insulation and gauges, are to be generally examined. Surveyors are to confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules and that the safety devices have been tested. Pressure vessels for process and drilling plant are to be examined in accordance with *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

2.3.9 For boilers, the safety devices are to be tested and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the Log Book.

2.3.10 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.3.11 Gas and crude oil burning systems are to be generally examined and safety devices tested. Surveyors are to confirm that Periodical Surveys have been carried out as required by *Pt 1, Ch 3, 10 Boilers*.

2.3.12 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions, so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled, they should be tested in the automatic mode.

2.3.13 Bonding straps for the control of static electricity and earthing arrangements are to be examined, where fitted.

2.3.14 For units having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.3.15 For units fitted with a dynamic positioning system and/or a thruster-assisted positional mooring system, the control system and associated machinery items are to be generally examined and tested under operating conditions to an approved Test Schedule.

2.3.16 For units fitted with automation equipment for main propulsion, essential auxiliary and emergency machinery, a general examination of the equipment and arrangements is to be carried out. Records of changes to the hardware and software used for controlling and monitoring systems for propelling and essential auxiliary machinery since the original issue (and their identification) are to be reviewed by the attending Surveyor. Satisfactory operation of the safety devices and controls systems is to be verified.

2.3.17 For units fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine; where possible, this is to include a running test under load.
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.3.18 Dead unit starting arrangements for bringing machinery into operation without external aid are to be tested to the Surveyor's satisfaction.

2.3.19 Ballast control and indicating systems, along with audible and visual alarms, are to be examined and tested at both the main control station and each of the independent local control stations.

2.3.20 For self-elevating units, the jacking gear machinery and associated control system, including locking devices, are to be generally examined. A planned cycle is to be agreed with LR for the examination of critical components, i.e., pins, flexible hoses, couplings, gear reducers, etc., at each Annual Survey, supplemented where necessary by NDE, as agreed with LR.

2.3.21 Swivel stack including valves, manifolds and pipe connections are to be generally examined under working conditions, with special attention to damage due to mechanical handling, and all seals are to be checked for tightness. Suitable leakage tests may be carried out at the Surveyor’s discretion and results of the grease sampling programme provided upon request.

2.3.22 On a single point mooring installation, automatic warning alarms of load monitoring systems are to be tested.

2.4 Safety and communication systems and hazardous areas

2.4.1 The Surveyor is to be satisfied as to the efficient condition as far as practicable of the following systems, in accordance with *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*:

(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Ventilation arrangements in hazardous areas around turret, swivel stack and mud processing areas are to be generally examined.
(g) Protection system against flooding including:
    (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
    (ii) Bilge level detection and alarm systems on column- stabilised units and in machinery spaces on surface type units.
    (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.

(h) Verification of the operation of manual and/or automatic doors.
(i) Protection of accommodation areas against the ingress of smoke.

2.4.2 For units where flammable mixtures are or may be present, a general examination of electrical equipment located in hazardous areas and spaces is to be made, to ensure that it is suitable for the application and that the integrity of safe type electrical equipment has not been impaired due to corrosion, missing bolts, etc. Cable runs should be examined so far as can be seen for sheath and armouring defects and to ensure that means of supporting the cable are in good order. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation, see also *Pt 1, Ch 3, 2.2 Structure and equipment*.

2.4.3 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

2.4.4 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of *Pt 1, Ch 3, 10 Boilers* and *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

2.5 Production and oil storage units

2.5.1 For units with crude oil bulk storage tanks, in addition to the applicable requirements of *Pt 1, Ch 3, 2.1 General*, the following are to be dealt with where applicable:

(a) Examination of oil storage tank openings including gaskets, covers, coamings and screens.
(b) Examination of oil storage tank pressure/vacuum valves and flame screens.
(c) Examination of flame screens on vents to all bunker, oily ballast and oily slop tanks and void spaces, so far as is practicable.
(d) Examination of crude oil storage washing, bunker, ballast and vent piping systems, together with flame arresters and pressure/vacuum valves, as applicable above the upper deck within the oil storage tank area, including vent masts and headers.
(e) Verification that no potential sources of ignition such as loose gear, excessive products in the bilges, excessive vapours, combustible materials, etc., are present in or near the oil storage pump-room and that access ladders are in good condition.
(f) Examination of all pump-room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads.
(g) Verification that the pump-room ventilation system is operational, ducting intact, dampers operational and screens are clean.
(h) External examination of the piping and shut-off valves of oil storage tank and oil storage pump-room fixed firefighting system.
(i) Verification that the deck foam system and deck deluge system are in good operating condition.
(j) Examination of the condition of all piping systems in the oil storage pump-room so far as is practicable.
(k) Examination so far as is practicable of oil storage, ballast, bilges and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump-room bilge system, and checking that pump foundations are intact.
(l) Verification that installed pressure gauges on oil discharge lines and level indicator systems are operational.
(m) Verification that at least one portable instrument for measuring flammable vapour concentrations is available, together with a sufficient set of spares and a suitable means of calibration.
(n) Examination of any inert gas system, see 2.6.
(o) For units greater than 15 years of age, all ballast tanks adjacent (i.e., with a common plane boundary) to a cargo tank with any means of heating are to be examined. Thickness measurement is to be carried out where considered necessary by the Surveyor. Special consideration may be given by the Surveyor to those tanks or spaces where the coatings are found in GOOD condition, as defined in 1.5, at the previous Intermediate or Special Survey.
(p) For ballast tanks, in areas where substantial corrosion, as defined in *Pt 1, Ch 3, 1.5 Definitions*, has been noted, additional measurements are to be carried out in accordance with *Pt 1, Ch 3 Periodical Survey Regulations* of the Rules for Ships, as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.

2.5.2 Safety and communication systems and hazardous areas are to be examined in accordance with 2.4.

2.5.3 For units where the requirements of *Pt 1, Ch 2, 1.4 General* are applicable, the arrangements for fire protection, detection and extinction are to be examined and are to include:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).

(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump, can be operated separately so that sufficient water can be produced to meet the greatest calculated demand in a credible emergency scenario.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharges containers.
(i) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(j) Examination of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable.
(k) Verification that the fireman's outfits are complete and in good condition.
(l) Examination of the electrical installation in areas which may contain flammable gas or vapour and/or combustible dust to verify that it is in good condition and has been properly maintained.

2.5.4 For units with production and process plant in which *Pt 7, Ch 3 Fire Safety* applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the applicable requirements of 2.5.3. In addition, the passive fire protection systems to the topsides process modules and associated plant shall be examined to verify, so far as practicable, that no significant changes have been made to the arrangement of structural fire protection.

2.5.5 In addition to the applicable requirements of*Pt 1, Ch 3, 2.1 General* , for units with a process plant facility having a **PPF** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the process plant facility for review and agreement by LR from the Survey aspects in advance of the first survey, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.5.6 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components to the process plant facility referred to in 2.5.5 as applicable, see also *Pt 3, Ch 8 Process Plant Facility*:

- Major equipment and structures of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.
- Pressure vessels are to be subject to survey in accordance with the requirements of *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*, see also 2.5.7.

2.5.7 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, see 2.5.5.

2.5.8 If the process plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the process plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

2.6 Inert gas systems

2.6.1 For inert gas systems, where fitted, the following are to be dealt with:

(a) External examination of the condition of piping, including vent piping, above the upper deck in the crude oil storage tank area and overboard discharges through the shell as far as practicable, together with components for signs of corrosion or gas leakage/effluent leakage.
(b) Verification of the proper operation of both inert gas blowers.
(c) Checking the scrubber room ventilation system.
(d) Checking, so far as is practicable, of the deck water seal for automatic filling and draining and checking for presence of water carry-over. Checking the operation of the non-return valve.

(e) Testing of all remotely operated or automatically controlled valves including the flue gas isolating valve(s).
(f) Checking the interlocking features of soot blowers.
(g) Checking the gas pressure regulating valve automatically closes when the inert gas blowers are secured.
(h) Checking, so far as is practicable, the following alarms and safety devices of the inert gas system, using simulated conditions where necessary:
  (i) High oxygen content of gas in the inert gas main.
  (ii) Low gas pressure in the inert gas main.
  (iii) Low pressure in the supply to the deck water seal.
  (iv) High temperature of gas in the inert gas main.
  (v) Low water pressure to the scrubber.
  (vi) Accuracy of portable and fixed oxygen measuring equipment by means of calibration gas.
(i) Checking of the interlocking features and positive isolation for tank isolation.

2.7 Drilling units

2.7.1 In addition to the applicable requirements of *Pt 1, Ch 3, 2.1 General*, for units having a **DRILL** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the drilling plant facility for review and agreement by LR from the survey aspect in advance of the first survey, see *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.7.2 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components of the drilling plant facility referred to in 2.7.1, as applicable, see also *Pt 3, Ch 7 Drilling Plant Facility*:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their control systems.
- Choke manifold and associated valves.
- Bulk storage.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick and hoisting, rotation and pipe handling equipment.
- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.
- Well protection valve and control systems.

2.7.3 Safety and communication systems and hazardous areas are to be examined in accordance with*Pt 1, Ch 3, 2.4 Safety and communication systems and hazardous areas*.

2.7.4 Pressure vessels forming part of the drilling plant facility are to be subject to surveys in accordance with the requirements of *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*, see also 2.7.5.

2.7.5 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, see 2.7.1.

2.7.6 If a drilling plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the drilling plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

■ *Section 3* Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements* are to be complied with, so far as applicable.

3.2.2 A general examination of salt-water ballast spaces is to be carried out by the Surveyor as required by *Pt 1, Ch 3, 3.2 Intermediate Surveys* and *Pt 1, Ch 3, 3.2 Intermediate Surveys*. If such examinations reveal no visible structural defects, the examination may be limited to a verification that the protective coating remains in GOOD or FAIR condition, as defined in *Pt 1, Ch 3, 1.5 Definitions*. When considered necessary by the Surveyor, thickness measurement of the structure is to be carried out.

3.2.3 For all units over five years of age and up to 10 years of age, representative salt-water ballast tanks and other spaces are to be examined as follows:

- **Column-stabilised units and tension-leg units**

  Representative ballast tanks in pontoons, lower hulls, and free-flooding compartments as accessible, and at least two ballast tanks in columns and upper hull, if applicable.
- **Self-elevating units**

  Representative ballast tanks and at least two representative pre-load tanks. Accessible free-flooding compartments in mat or footings.
- **Ship units and other surface type units**

  One peak tank and at least two other representative ballast tanks between the peak bulkheads used primarily for water ballast.
- **Deep draught caissons**

  Representative ballast tanks where accessible.
- **All unit types**

  Particular attention is to be given to corrosion control systems in ballast tanks, free-flooding areas and other locations subjected to sea-water from both sides where accessible.

For tanks other than independent double bottom tanks, where a protective coating is found in POOR condition, as defined in*Pt 1, Ch 3, 1.5 Definitions*, or other defects are found, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. For independent double bottom tanks where substantial corrosion or other defects are found, the examination is to be extended to other ballast tanks of the same type.

3.2.4 For all unit types over 10 years of age, the following is required:

(a) All salt-water ballast tanks and free-flooding areas are to be examined.
(b) The anchors on units assigned the character **(1)** are to be partially lowered and raised using the windlass.

3.2.5 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey as having substantial corrosion, see Section 5.

3.2.6 In addition to 3.2.1 to 3.2.7 on units with crude oil bulk storage tanks, the following are to be dealt with where applicable:

(a) An examination of oil storage, crude oil washing, bunker, ballast, steam and vent piping on weather decks, as well as vent masts and headers. If, upon examination, there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, gauged, or both.
(b) A general examination within the areas deemed as dangerous, such as cargo pump-rooms and spaces adjacent to and zones above cargo tanks, for defective and non-certified safe type electrical equipment, improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out. If the unit is not in a gas-free condition, the results of previously recorded test readings may be accepted.

3.2.7 For all units, the electrical generating sets are to be examined under working conditions to verify compliance with *Pt 6, Ch 2, 2.2 Number and rating of generators and converting equipment*.

3.2.8 The following are to be examined where accessible:

- Turret and circumturret structure.
- Turret bearings and seals.
- Swivel stack bearings and seals.

- Mooring arm pivots and bearings.

3.2.9 For units with crude oil bulk storage tanks, in addition to 3.2.6, the following is required for units over 10 years and less than 15 years of age:

(a) Overall survey of all salt-water ballast tanks, including any combined salt-water ballast/crude oil storage tanks.
(b) Overall survey of at least two representative crude oil storage tanks.
(c) Close-up Survey of salt-water ballast tanks to the same extent as the previous Special Survey and two combined cargo/ballast tanks. Where protective coatings are found to be in GOOD condition, as defined in*Pt 1, Ch 3, 1.5 Definitions* , the extent of Close-up Survey may be specially considered.
(d) The thickness measurement requirements of 3.2.7 are to be complied with. In areas where substantial corrosion, as defined in *Pt 1, Ch 3, 1.5 Definitions*, has been noted, additional measurements are to be carried out to the satisfaction of the Surveyor. The survey will not be considered complete until these additional thickness measurements have been carried out.
(e) Machinery and boiler spaces, including tank tops, bilges and cofferdams, sea suctions and overboard discharges, are to be generally examined.

3.2.10 For units with crude oil bulk storage tanks, in addition to 3.2.8 and 3.2.11, the following is required for units over 15 years of age:

(a) A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, see *Pt 1, Ch 3, 7.1 General 7.1.2* of the Rules for Ships).
(b) Pressure testing of cargo and ballast tanks is to be carried out if deemed necessary by the attending Surveyor.

3.2.11 For **natural gas fuel installations** *see also Pt 1, Ch 3, 21.7 Intermediate Surveys*.

■ *Section 4* Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys in lieu of Docking Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition, see also *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.

4.2 Docking surveys

4.2.1 Where a unit is in dry dock or on a slipway, it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary, for the examination of the shell, including bottom and bow plating, keel, sponsons and appendages, stern, sternframe and rudder. The rudder is to be lifted for examination of the pintles if considered necessary by the Surveyor.

4.2.2 For self-elevating units, the leg footings and those parts of the leg and hull that are normally under water are to be examined. The connections between leg chords and the footings or mats are to be inspected and subjected to NDE.

4.2.3 For self-elevating units, at each Docking Survey or In-Water Survey coinciding with Special Survey, the Surveyor is to be satisfied with the internal condition of the leg footings or mats. Leg connections to leg pads are to be nondestructively tested. Non destructive testing may be required of areas considered to be critical or found to be suspect by the Surveyor. Non-metallic expansion pieces in the main seawater cooling and circulating systems are to be examined both externally and internally.

4.2.4 For column-stabilised units, external surfaces of the upper hull or platform, footings, pontoons or lower hulls, underwater areas of columns, bracing and their connections, sea chests, and propulsion units as applicable, are to be selectively cleaned and examined to the satisfaction of the attending Surveyor. Non-destructive testing may be required of areas considered to be critical or found to be suspect by the Surveyor.

4.2.5 The shell plating is to be examined for excessive corrosion, deterioration due to chafing or contact with the ground and for undue unfairness or buckling. Special attention is to be given to the connections between the bilge strakes and bilge keels.

4.2.6 The external cathodic protection system and coatings are to be examined.

4.2.7 The clearances in the rudder bearings are to be measured. Where applicable, pressure testing of the rudder may be required if deemed necessary by the Surveyor.

4.2.8 The sea connections and overboard discharge valves and cocks and their attachments to the hull are to be examined.

4.2.9 Thrusters, propeller, sternbush and sea connection fastenings and the gratings at the sea inlets are to be examined.

4.2.10 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained.

4.2.11 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, see also *Pt 1, Ch 3, 5.3 Examination and testing*. For units having a positional mooring notation in accordance with *Pt 3, Ch 10 Positional Mooring Systems*, the positional mooring systems and associated equipment are also to be examined.

4.2.12 For electrical equipment survey requirements of units five years old and over, see *Pt 1, Ch 3, 9.2 Complete Surveys*.

4.3 In-water surveys

4.3.1 The Classification Committee will accept an In-Water Survey in lieu of the intermediate docking survey between Special Surveys on units other than those where an **OIWS** notation is assigned, *see Pt 1, Ch 2, 2.4 Class notations (hull/structure)*. where suitable protection is applied to the underwater portion of the hull and provided the information in paragraphs *Pt 1, Ch 3, 4.3 In-water surveys*. and *Pt 1, Ch 3, 4.3 In-water surveys* are complied with.

Note statutory regulations (*SOLAS - International Convention for the Safety of Life at Sea* and *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)*) regarding the requirements for In-Water Surveys at intermediate and Special Surveys shall also apply where applicable.

4.3.2 Special arrangements must be incorporated into the unit's design or otherwise provided to allow adequate survey of thrusters, stern bearings, rudder bearings, sea suctions and valves, etc., *see Pt 3, Ch 1, 2.1 General*.

4.3.3 Special consideration shall be given to ascertaining rudder bearing clearances and sternbush clearances, based on a review of the operating history, onboard testing and stern bearing oil analysis. These considerations are to be included in the proposals, see 4.3.5.

4.3.4 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as practicable.

4.3.5 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.6 A planned procedure for the routine inspection of the underwater areas is to be agreed between the Owners and LR. A procedure document is to be placed on board the unit and made available to the Surveyor. Where survey experience indicates that modifications are required to the inspection procedures, the procedure document is to be modified to the satisfaction of LR.

4.3.7 The In-water Survey is to be carried out at an agreed geographical location, with the Surveyor to LR satisfied that the unit at a suitable draught and the conditions satisfactory for diver or ROV inspection. The in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver/ROV operator. The Survey is to be witnessed by the Surveyor. This requires the Surveyor to be on board while the Survey is carried out, to the extent necessary to control the process. The Surveyor may extend the scope of Survey if deemed necessary.

4.3.8 In general, the In-water Survey is to be carried out using LR approved diving company with suitably qualified divers. Alternatively, the In-water Survey may be carried out using a LR approved ROV operator, subject to agreement with the attending LR Surveyor.

4.3.9 The efficient condition of the cathodic protection system and the high resistance paint is to be confirmed at each In-water Survey to the satisfaction of the Surveyors, in order that the **OIWS** notation can be maintained.

4.3.10 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the unit be dry-docked, in order that a more detailed survey can be undertaken and the necessary work carried out.

4.3.11 Diver/ROV-assisted surveys are not acceptable for the periodic survey inspections of primary bracing members, or intersections of bracings with columns or pontoons, or column to pontoon intersections on column-stabilised units, except in exceptional circumstances when specially agreed with the Classification Committee and the procedures have been approved, see also *Pt 1, Ch 3, 2.2 Structure and equipment*.

4.3.12 Turret and bearings below water level, underwater parts of mooring towers and/or articulated towers (where applicable), chain stoppers, chain cables and mooring lines/chains are to be examined as far as practicable during In-water Surveys. On tension-leg units, tethers and their upper and lower connections are to be examined.

4.3.13 For electrical equipment survey requirements of units five years old and over, see*Pt 1, Ch 3, 9.2 Complete Surveys*.

4.3.14 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.13.

4.3.15 For self-elevating units, the requirements of *Pt 1, Ch 3, 4.2 Docking surveys* are to be undertaken as far as practicable with due consideration to the operation and location of the unit.

Section 5
Special Survey – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull/structure and related piping is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to periodical surveys being carried out as required by the Regulations.

5.1.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

5.1.3 The requirements of *Pt 1, Ch 3, 1.6 Planned survey programme* are to be complied with as applicable for all units.

5.1.4 The requirements of *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements* are to be complied with, as applicable, for all units.

5.1.5 A Docking Survey, or an In-water Survey in lieu of a Docking Survey, in accordance with the requirements of *Pt 1, Ch 3, 4 Docking Surveys and In-water Surveys – Hull and machinery requirements* is to be carried out as part of the Special Survey.

5.1.6 **Ship units and other surface type units**. For units with crude oil bulk storage tanks, the requirements of *Pt 1, Ch 3, 7 Special Survey - Oil tankers (including ore/oil ships and ore/bulk/oil ships) - Hull requirements* of the Rules for Ships are to be complied with as applicable. For units with liquefied gas cargo containment systems, the additional requirements of *Pt 1, Ch 3, 9 Ships for liquefied gases* of the Rules for Ships are to be complied with as applicable.

5.2 Preparation

5.2.1 The unit is to be prepared as necessary for the Surveyors to gain proper access for the careful inspection and examination of all items listed in this Section. Voids and closed spaces are to be thoroughly ventilated to ensure adequate levels of oxygen in the air, fuel tanks, oil storage tanks and other similar spaces are to be gas freed and cleaned as necessary and paint lining, insulation and other coatings and coverings are to be removed locally if required by the Surveyors.

5.2.2 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping and found sound and adhering satisfactorily to the steel.

5.2.3 **Ship units and other surface type units**. The requirements of *Pt 1, Ch 3, 5.2 Preparation*of the Rules for Ships are to be complied with, as applicable.

5.3 Examination and testing

5.3.1 All spaces within the hull/structure and superstructure are to be subject to an overall survey and examination.

5.3.2 Watertight integrity of tanks, bulkheads, hull, decks and other compartments is to be verified by visual inspection.

5.3.3 **Ship units and other surface type units**. The requirements of *Pt 1, Ch 3, 5.3 Examination and testing* of the Rules for Ships are to be complied with, as applicable. Testing of crude oil storage tanks is to be carried out as deemed necessary by the attending Surveyor. For units assigned an **ESP** notation, the requirements of *Pt 1, Ch 3, 7.5 Testing* of the Rules for Ships are to be complied with as applicable, see also 5.3.15.

5.3.4 For tank internal examinations, the requirements of *Pt 1, Ch 3, 5.3 Examination and testing 5.3.2*of the Rules for Ships are to be complied with as applicable.

5.3.5 In spaces used for salt-water ballast, excluding double bottom tanks, where a protective coating is found in POOR condition, as defined in *Pt 1, Ch 3, 1.5 Definitions*, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the space in question being internally examined and gauged as necessary at Annual Surveys.

5.3.6 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in *Pt 1, Ch 3, 1.5 Definitions*, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

5.3.7 Double bottom, deep, ballast, peak and other tanks, including cargo holds assigned also for the carriage of salt-water ballast, are to be tested with a head of liquid to the top of air pipes or to the top of hatches for ballast/cargo holds. Boundaries of fuel oil, lubricating oil and fresh water tanks are to be tested with a head of liquid to the maximum filling level of the tank. Tank testing of fuel oil, lubricating oil and fresh water tanks may be specially considered, based upon a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

5.3.8 Where repairs are effected to the shell plating or bulkheads, any tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.9 In units with crude oil storage tanks, all piping systems on deck and within the storage tanks and adjacent spaces are to be examined to ensure that tightness and condition remain satisfactory. Special attention is to be given to ballast piping in storage tanks and crude oil storage piping in ballast tanks, pump-rooms, pipe tunnels and void spaces.

5.3.10 Where substantial corrosion, as defined in *Pt 1, Ch 3, 1.5 Definitions*, is identified in crude oil storage tanks and is not rectified, this will be subject to re-examination at Annual and Intermediate Surveys and is to be gauged as necessary.

5.3.11 At the first Special Survey and at subsequent Special Surveys, representative tanks are to be examined by a Close-up Survey. The extent of the survey is to be agreed with LR in advance of the survey. For all units over 10 years of age, all salt-water ballast tanks and free-flooding areas where accessible are to be examined.

5.3.12 The attachment to the structure and condition of anodes in all tanks is to be examined.

5.3.13 In addition to the requirements of 5.3.1, columnstabilised units and tension-leg units are to have a complete bracing Close-up Survey consisting of a detailed dry examination of all bracings and their structural connections to columns and decks. The connections of columns to lower hulls, pontoons and upper hulls are to be examined. All critical regions defined in 2.2.3 are to be examined by approved methods of NDE, see also *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. Primary structure of the upper hull or platform which form 'Box' or 'I' type supporting structure and their end connections are to be examined. All free-flooding areas and sponsons are to be examined.

5.3.14 In addition to the requirements of 5.3.1, self-elevating units are to have a complete survey of all legs, footings and mats. Particular attention is to be given to the leg structure in way of the waterline. Tubular or similar type legs are to be examined externally and internally, including stiffeners and pin holes. All critical regions defined in*Pt 1, Ch 3, 2.2 Structure and equipment* are to be examined by approved methods of NDE, including the leg connections to footings or mats, see also *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*. Jetting piping systems or other external piping, particularly where penetrating footings or mats, are to be examined. Where the spud cans or mat are partly or entirely obscured below the mud line where the Special Survey is otherwise being completed, consideration may be given to postponement of the examinations until the next Rig move.

5.3.15 In addition to the requirements of 5.3.1, surface type units are to have a Close-up Survey carried out in accordance with an agreed programme, see also *Pt 1, Ch 3, 1.6 Planned survey programme*. The programme should identify all critical areas of primary structure components and connections within compartments to be surveyed. Special attention is to be given to underdeck structure supporting topside equipment, flare stack and cranes, etc. The Surveyor may extend the Close-up Survey if deemed necessary, taking into account the maintenance of the tanks under survey and the condition of the corrosion prevention system. For areas in tanks where coatings are found to be in GOOD condition, as defined in*Pt 1, Ch 3, 1.5 Definitions* , the extent of Close-up Survey may be specially considered.

5.3.16 In addition to the requirements of 5.3.1, structural appendages and ducts for positioning units, sponsons and positioning spuds on surface type units are to be examined.

5.3.17 On all units, careful examination is to be made of those parts of the structure particularly liable to excessive corrosion, or to deterioration or damage from causes such as chafing, lying on the sea bed or handling of drilling equipment, stores, etc., and due to water collection in corners of bulkheads and on weather decks, and in other exposed areas.

5.3.18 All decks including helidecks and their supporting structure, deck-houses, casings and superstructures are to be examined. Where aluminium alloy is used in the structure, bimetallic joints are to be examined as far as practicable. Lifeboat and winch platforms and their supporting structures are to be examined.

5.3.19 Wood decks and sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is

found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, see also *Pt 1, Ch 3, 1.2 Surveys for damage or alterations*.

5.3.20 Primary bulkheads in the upper hull of column stabilised units and in the hull of self-elevating units are to be examined. Particular attention is to be given to the structure below and derrick sub-structures and supports under process plant, drilling derricks and other heavy equipment. Bulkheads adjacent to leg wells, turrets and moonpools are to be examined. Bulkhead penetrations in way of doors and other openings are to be examined.

5.3.21 A Close-up Survey of structure around external and internal turrets is to be held as per an agreed planned survey programme. Thickness measurements are to be made as per the agreed planned survey programme, see*Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys* . Turret bearings are to be examined in accordance with the manufacturers' recommendations and agreed survey programme. Records of analyses of turret and swivel bearing seals and lubricants are to be examined by the Surveyors for compliance to manufacturers' standards and/or recommendations.

5.3.22 Mooring buoys, mooring arms and yokes, mooring towers, and other similar special features of the installation are to be specially examined in accordance with an agreed planned survey programme.

5.3.23 For deep draught caisson units having combined oil/ballast tanks which for operational requirements are always full, the periodic survey programme is to be agreed to at the design stage. Owners may consider installing suitable steel coupon plates in these tanks, where practicable, to monitor corrosion. Where coupon plates are fitted, their position will be specially considered and they are to be electrically insulated from the unit. Weight and thickness of the coupon plates are to be recorded and reported at each special survey.

5.3.24 For tension-leg units, a Close-up Survey of the structure in way of tethers is to be carried out.

5.3.25 For units having a **DRILL** notation, the drilling derrick, including bolting arrangements is to be examined. Other structural components and supports forming part of the drilling plant are to be examined and tested as necessary, see also *Pt 1, Ch 3, 2.7 Drilling units*.

5.3.26 For production units with a process plant facility having a PPF notation, all plant supporting structure, including bracing trusses and skids, is to be examined, see also *Pt 1, Ch 3, 2.5 Production and oil storage units*.

5.3.27 The requirements for thickness determination of the structure of all unit types are to be in accordance with *Pt 1, Ch 3, 5.4 Thickness measurement*.

5.3.28 Crane pedestals and similar supporting structures to access gangways and flare booms, masts and standing rigging are to be examined.

5.3.29 At the second Special Survey and subsequent Special Surveys, chain lockers are to be cleaned and examined internally.

5.3.30 For disconnectable units and mobile offshore units assigned the character figure **(1)**, anchors are to be examined. Anchors are to be partially lowered and raised by the windlass or winch as applicable. The chain cables and wire rope cables are to be examined as far as practicable. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The anchor windlass or winch is to be examined. For equipment forming part of a positional mooring system, see*Pt 1, Ch 3, 5.5 Positional mooring systems*.

5.3.31 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. In addition, the Surveyor is to examine internally air pipe heads in accordance with the requirements of Table 3.1.

5.3.32 The Surveyor is to be satisfied as to the efficient condition of the helm indicator, protection of aft steering wheel and gear on self-propelled units.

5.3.33 Foundations and supporting headers, brackets and stiffeners for drilling-related apparatus, where attached to hull, deck, substructure or deck-house, are to be examined.

5.3.34 Foundations of machinery are to be examined.

5.4 Thickness measurement

5.4.1 The requirements for thickness measurements given in *Pt 1, Ch 3, 1.8 Thickness measurement at survey* are to be complied with.

5.4.2 In addition to the thickness measurements required by 5.4.1 to ascertain local wastage, thickness measurement is to be carried out on units with crude oil bulk storage tanks at the first Special Survey and at subsequent Special Surveys, in accordance with the requirements of *Pt 1, Ch 3, 5.6 Thickness measurement* and *Pt 1, Ch 3, 7.7 Thickness measurement* of the Rules for Ships, as applicable.

Table 3.5.1 Air pipe head internal examination requirements (applicable for automatic air pipe heads installed on exposed decks of all units)

Special Survey I (Units 5 years old)	Special Survey II (Units 10 years old)	Special Survey III (Units 15 years old) and subsequent
(1) Two air pipe heads (one port and one starboard) on exposed decks in the forward 0,25L. See Notes 1 to 5	(1) All air pipe heads on exposed decks in the forward 0,25L. See Notes 1 to 5	All air pipe heads on exposed decks. See Notes 1 to 6
(2) Two air pipe heads (one port and one starboard) on the exposed decks, serving spaces aft of 0,25L See Notes 1 to 5	(2) At least 20% of air pipe heads on exposed decks, serving spaces aft of 0,25L. See Notes 1 to 5	
NOTES		
1. Air pipe heads serving ballast tanks are to be selected where available. 2. The Surveyor is to select which air pipe heads are to be examined. 3. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other air pipe heads on exposed decks. 4. Where the inner parts of an air pipe head cannot be properly examined due to its design, it is to be removed in order to allow an internal examination. 5. Particular attention is to be given to the condition of the zinc coating in heads constructed from galvanised steel. 6. Exemption may be considered for air pipe heads where there is documented evidence of their replacement within the previous five years.		

5.4.3 Thickness measurements are to be carried out in accordance with *Table 3.5.2 Minimum Requirements for Thickness Measurements for Self-Elevating Units at Special Survey* for self-elevating units and *Table 3.5.3 Minimum Requirements for Thickness Measurements for Column-Stabilized Units at Special Survey* for column stabilised units. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine areas of substantial corrosion. *Table 3.5.4 Requirements for Additional Thickness Measurements in way of Substantial Corrosion* may be used for these additional thickness measurements.

5.4.4 On all other unit types, thickness measurement is required at the second Special Survey and at subsequent Special Surveys. Thickness measurement of the primary hull structure is to include the shell plating of hulls, pontoons, columns, bracings, main strength decks, bulkheads, legs, footings, mats and the structure of representative salt-water ballast and pre-load tanks and other tanks and critical areas as required by the Surveyor, to determine the amount of any general diminution in thickness. The extent and location of such measurements are to be agreed by LR prior to each survey, see also *Pt 1, Ch 3, 1.6 Planned survey programme*.

Table 3.5.2 Minimum Requirements for Thickness Measurements for Self-Elevating Units at Special Survey

Special Survey I Age ≤ 5	Special Survey II 5< Age ≤ 10	Special Survey III 10 < Age ≤ 15	Special Survey IV and subsequent 15 < Age
(1) Suspect areas throughout the unit (particular attention to be paid to the legs in way of the Splash Zone).	(1) Suspect areas throughout the unit.	(1) Suspect areas throughout the unit.	(1) Suspect areas throughout the unit.
	(2) Legs in way of Splash Zone.	(2) Legs in way of Splash Zone.	(2) Legs in way of Splash Zone.
	(3) Primary application structures where wastage is evident.	(3) Representative gaugings, throughout, of special and primary application structures.	(3) Comprehensive gaugings, throughout, of special and primary application structures.

	(4) Representative gaugings of upper hull deck and bottom plating and internals of one preload tank.	(4) Leg well structure.	(4) Leg well structure.
		(5) Representative gaugings of deck, bottom, and side shell plating of hull and mat.	(5) Representative gaugings of deck, bottom, and side shell plating of hull and mat.
		(6) Representative gaugings of upper hull deck and bottom plating and internals of at least two preload tanks.	(6) Substructure of derrick as deemed necessary.
			(7) Representative gaugings of internals of all preload tanks.
Note 1. Structural application designation (Special, Primary, Secondary) are defined in IACS Recommendation No. 11			

Table 3.5.3 Minimum Requirements for Thickness Measurements for Column-Stabilized Units at Special Survey

Special Survey I Age ≤ 5	Special Survey II 5 > Age ≤ 10	Special Survey III 10 > Age ≤ 15	Special Survey IV and subsequent 15 > Age
(1) Suspect areas throughout the unit.	(1) Suspect areas throughout the unit.	(1) Suspect areas throughout the unit.	(1) Suspect areas throughout the unit.
(2) Columns and bracings where wastage is evident in Splash Zone.	(2) Representative gaugings of columns and bracings in Splash Zone together with internals in way as deemed necessary.	(2) Representative gaugings, throughout, of special and primary application structures.	(2) Comprehensive gaugings, throughout, of special and primary application structures.
	(3) Special and primary application structure where wastage is evident.	(3) One Transverse Section (Girth Belt) of each of 2 columns and 2 bracings in Splash Zone together with internals in way as deemed necessary.	(3) One Transverse Section (Girth Belt) of each of one-half of the columns and bracings in Splash Zone and internals in way as deemed necessary (i.e., gauge half of the unit's columns and bracings in Splash Zone).
		(4) Lower hulls in way of mooring lines where wastage is evident.	(4) Lower hulls in way of mooring lines where wastage is evident.
		(5) One Transverse Section (Girth Belt) of each lower hull between one set of columns.	(5) One Transverse Section (Girth Belt) of each lower hull between one set of columns.
			(6) Representative gaugings of substructure of drilling derrick.
Note Structural application designation (Special, Primary, Secondary) are defined in IACS Recommendation No. 11			

Table 3.5.4 Requirements for Additional Thickness Measurements in way of Substantial Corrosion

Structural Member	Extent Of Measurement	Pattern Of Measurement
Plating	Suspect area and adjacent plates.	5 point pattern over 1 square meter.
Stiffeners	Suspect area.	3 measurements each in line across web and flange.

5.4.5 A report is to be prepared by the qualified firm carrying out the thickness measurements. The report is to give the location of measurement and the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the Operator.

5.4.6 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an Authorising Surveyor.

5.5 Positional mooring systems

5.5.1 On units fitted with positional mooring equipment which have been assigned a special features notation in accordance with *Pt 3, Ch 10 Positional Mooring Systems*, the requirements for annual surveys in *Pt 1, Ch 3, 2.2 Structure and equipment* are to be complied with.

5.5.2 Where practicable, mooring cables, chains and anchors are to be lifted to the surface for detailed inspection in accordance with 5.5.3 and 5.5.4 at each Special Survey. Alternatively, in situ inspection, using acceptable techniques, will be considered by LR when requested. See also *Pt 3, Ch 17 Appendix B Guidelines on the Inspection of Positional Mooring Systems* for guidance notes on the inspection of positional mooring systems.

5.5.3 As far as practicable, the Surveyor is to determine the general condition of the mooring system, including cables, chains, fibre ropes, fittings, fairleads, connections and equipment. Particular attention is to be given to the following:

- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

5.5.4 Anchors of mobile offshore units are to be cleaned and examined. Wire rope anchor cables are to be examined. If cables are found to contain broken, badly corroded or bird caging wires, they are to be renewed. Chain cables are to be ranged and examined. Maximum acceptable diminution of anchor chain in service will normally be limited to a two per cent reduction from basic chain diameter (basic chain diameter can be taken as the diameter, excluding any design corrosion allowance, which satisfies the Rule requirement for minimum factors of safety).

5.5.5 The windlasses or winches are to be examined.

5.5.6 Structure in way of anchor racks and anchor cable fairleads is to be examined.

■ *Section 6*
Machinery Surveys – General requirements

6.1 Annual, Intermediate, Docking and In-water Surveys

6.1.1 For Annual, Intermediate, Docking and In-water Surveys, see *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements*.

6.1.2 For laid-up machinery, see *Pt 1, Ch 3, 20 Laid-up machinery*.

6.2 Complete Surveys

6.2.1 While the unit is in dry dock or subject to In-water Surveys, all openings to the sea in the machinery spaces, pump-rooms and other spaces, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

6.2.2 All shafts (except screw shafts and tube shafts, for which special arrangements are detailed in *Pt 1, Ch 3, 12 Screwshafts, tube shafts and propellers*), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.3 An examination is to be made of all reduction gears, complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.4 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and mooring winches and associated driving equipment, where fitted.
(d) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.
(e) The holding-down bolts and chocks of main and auxiliary engines, gear cases, thrust blocks and intermediate shaft bearings.
(f) Where Thrusters are fitted and have been assigned the Descriptive Note ThCM, the degree of inspection required whilst in dock will be determined by the analysis of Condition Monitoring records. Refer to ShipRight Machinery Planned Maintenance and Condition Monitoring, Section 6.

6.2.5 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.6 The valves, cocks and strainers of the bilge system, including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The fuel oil, feed, lubricating oil and cooling water systems, also the ballast connections and blanking arrangements to deep tanks, pre-load tanks or brine tanks which may carry different liquid, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.7 Fuel tanks which do not form part of the unit's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel oil tanks are to be examined, so far as is practicable.

6.2.8 Arrangements are to be made by Owners for opening up and examination of all sea connections afloat at five-yearly intervals.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to under operating conditions to an approved test scheule.

6.2.10 On units fitted with a dynamic positioning system and/or thruster-assisted positional mooring system, the control system and associated machinery items, including pressure vessels, are to be examined and tested to demonstrate that they are in good working order.

6.2.11 In addition to the above, detailed requirements for steam and gas turbines, engines, electrical installations and boilers are given in *Pt 1, Ch 3, 7 Turbines – Detailed requirements* respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Classification Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g., vibration indicators) and operational records.

6.2.12 For self-elevating units, the following essential parts of the elevating and lowering machinery, which are critical to the safety of the unit, are to be specially examined:

(a) Couplings, pinions and gears of the climbing pinion gear train of rack and pinion systems are to be examined and NDE is to be carried out to the Surveyor's satisfaction.
(b) Attachment of the reduction gear case to the jackcases or other supporting structure is to be examined for wear and bolting arrangements examined for security.
(c) Leg guides and shock pads are to be examined for wear.
(d) The fixation system, where fitted, is to be examined for wear and satisfactory operation/engagement.
(e) Grease injection lubrication system is to be examined for damage to piping and nozzles. Satisfactory operation of system is to be verified.
(f) Operational tests of the jacking system are to be carried out to the Surveyor's satisfaction.

6.2.13 Where an approved planned maintenance scheme is in operation, surveys may be carried out in accordance with *Pt 1, Ch 2, 3.5 Existing installations – Periodical Surveys*.

6.2.14 For **natural gas fuel installations** *see* also *Pt 1, Ch 3, 21.7 Intermediate Surveys* and *Pt 1, Ch 3, 21.8 Complete Surveys – General requirements*.

■ *Section 7*
Turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of *Pt 1, Ch 3, 6 Machinery Surveys – General requirements* are to be complied with.

7.1.2 The working parts of the main engines and attached pumps, and of auxiliary machinery used for essential services, are to be opened out and examined, including:

- For turbine machinery:
    - Bulkhead stop valves and manoeuvring valves.
    - Blading and rotors.
    - Flexible couplings.
    - Casings.

7.1.3 In gas turbines and free piston gas generators, the following parts are also to be opened out and examined:

- Impellers or blading.
- Rotors and casings of the air compressors.
- Combustion chambers and burners.
- Intercoolers and heat exchangers.
- Gas and air piping, and fittings.
- Starting and reversing arrangements.

7.1.4 Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened out and examined:

- Gas and air compressor cylinders and pistons.
- Compressor end covers.
- Valves and valve gear.
- Fuel pumps and fittings.
- Synchronising and control gear.
- Cooling system.
- Explosion relief devices.
- Gas and air piping.
- Receivers and valves, including bypass arrangements.

7.1.5 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for essential services, are to be examined to the satisfaction of the Surveyor, and if it is considered necessary, they are to be tested.

7.1.6 The manoeuvring of the engines is to be tested under working conditions.

7.1.7 Exhaust steam turbines supplying power for main propulsion purposes, together with their gearing and appliances, steam compressors or electrical machinery, are to be examined, so far as is practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined, so far as is practicable.

7.1.8 In units having essential auxiliary machinery driven by engines, the prime movers of these auxiliaries are to be examined as detailed in Section 8.

■ *Section 8*
Reciprocating internal combustion engines – Detailed requirements

8.1 Scope

The requirements of this Section are applicable to reciprocating internal combustion engines, operating on liquid, gas or dual fuel, providing power for services essential to the safety of the unit.

8.2 Complete Surveys

8.2.1 The requirements of *Pt 1, Ch 3, 6 Machinery Surveys – General requirements* are to be complied with.

8.2.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Pistons, piston rods, connecting rods, crossheads and guides.
- Valves and valve gear.
- Crankshafts and all bearings.
- Crankcases, bedplates and entablatures.
- Crankcase door fastenings, explosion relief devices and scavenge relief devices.
- Scavenge pumps, scavenge blowers, superchargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.2.3 Selected pipes in the starting air system are to be removed for internal examination and thickness measurement is to be carried out where considered necessary by the Surveyor. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.2.4 The electric ignition system, if fitted, is to be examined and tested.

8.2.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

8.2.6 Where steam is used for essential purposes, the condensing plant, feed pumps and fuel oil burning plant are to be examined and the steam pipes examined and tested as detailed in*Pt 1, Ch 3, 11 Steam pipes*.

■ *Section 9*
Electrical equipment

9.1 Annual and Intermediate Surveys

9.1.1 The requirements of *Pt 1, Ch 3, 2 Annual Surveys – Hull and machinery requirements* are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be subdivided, or equipment which may be damaged disconnected, for the purpose of this test.

9.2.2 The fittings on the main and emergency switchboard, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices, including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 Air circuit-breakers for essential or emergency services and rated at 800A and above are to be surveyed to ensure that the manufacturer's recommended number of switching options has not been exceeded. See *Pt 6, Ch 2, 7.3 Circuit-breakers 7.3.6* of the Rules for Ships. Where a breaker is not fitted with an automatic counter, a written record is to be kept.

9.2.5 The electric cables are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.6 The generator prime movers are to be surveyed as required by *Pt 1, Ch 3, 7 Turbines – Detailed requirements* and *Pt 1, Ch 3, 8 Reciprocating internal combustion engines – Detailed requirements* and the governing of the engines tested. The motors concerned with essential services, together with associated control and switch gear, are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.7 Where transformers associated with supplies to essential services are liquid immersed, the Owner is to arrange for samples of the liquid to be taken and tested for dissolved gases, breakdown voltage, acidity and moisture by a competent testing authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be made available to the Surveyor on request.

9.2.8 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.9 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

9.2.10 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as is practicable.

9.2.11 Where the unit is electrically propelled, the propulsion motors, generators, propulsion transformers, propulsion conversion equipment, cables, harmonic filters, neutral earthing resistors, dynamic breaking resistors and all ancillary electrical equipment that forms part of the propulsion drive and control system, exciters and ventilating plant (including coolers) associated therewith are to be surveyed and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and sliprings. Where practicable, the low voltage and high voltage windings of resin coated propulsion transformers are to be subjected to boroscopic inspection, to assess the physical condition of their insulation and for signs of mechanical and thermal damage. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil, if used, is to be tested in accordance with 9.2.7. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency over-speed governors are to be tested.

9.2.12 A general examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe type electrical equipment has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation. Particular attention should be given to cable runs in way of articulated joints and breaks in process deck boundaries.

9.2.13 Shipboard Automatic and Remote-Control Systems. In addition to the requirements of Annual Surveys, the following parts are to be examined:

(a) Control actuators: All mechanical, hydraulic, and pneumatic control actuators and their power systems are to be examined and tested as considered necessary by the Surveyor.
(b) Electrical equipment: The insulation resistance of windings of electrical control motors or actuators is to be measured, with all circuits of different voltages above ground being tested separately to the Surveyor's satisfaction.
(c) Unattended plants: Control systems for unattended machinery spaces are to be subjected to dock trials at reduced power on the propulsion engine to ensure the proper performance of all automatic functions, alarms and safety systems.

9.2.14 For production and oil storage units five years old and over, 9.2.11 is to be complied with. In addition, an electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out.

Section 10
Boilers

10.1 Frequency of surveys

10.1.1 All boilers, economisers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle. The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey.

10.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler, not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:

(a) External examination of the boiler.
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear).
(c) Operational tests of the boiler protective devices.
(d) Review of the following records since the previous Boiler Survey:

- Operation.
- Maintenance.
- Repair history.
- Feedwater chemistry.

In this context, 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts, or delays incurred by action taken to avoid severe weather conditions.

10.1.3 An external survey of boilers, including tests of safety and protective devices, and tests of safety valves using their relieving gear, is to be carried out annually within the range dates of the Annual Survey of the unit. For exhaust gas heated economisers, the safety valves are to be tested by the Chief Engineer at sea within the range dates of the Annual Survey. This test is to be recorded in the Log Book and reviewed by the attending Surveyor prior to crediting the Annual Survey.

10.2 Scope of surveys

10.2.1 At the surveys described in 10.1, the boilers, superheaters, economisers and air heaters are to be examined internally on the water-steam side and the fire side. Where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thicknesses of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The safety valves and principal mountings on boilers, superheaters and economisers are to be examined and opened up as necessary by the Surveyor. The adjustment of safety valves is to be verified during each boiler internal survey. Boiler safety valves and their relieving gear are to be examined and tested to verify their satisfactory operation. Safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable, provided that the valves lift at not more than 103 per cent of the approved design pressure. However, for exhaust gas heated economisers, if steam cannot be raised in port, the safety valves may be set by the Chief Engineer at sea, and the results recorded in the Log Book and reviewed by the attending Surveyor. The following records since the previous Boiler Survey are to be reviewed as part of the survey:

- Operation.
- Maintenance.
- Repair history.
- Feedwater chemistry.

The remaining mountings are to be examined externally and, if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

10.2.2 In addition to the requirements of 10.2.1, in exhaust gas heated economisers of the shell type, all accessible welded joints are to be subjected to a visual examination in order to identify any evidence of cracking. Non-destructive testing may be required for this purpose and may be requested by the Surveyor.

10.2.3 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

10.2.4 The fuel oil burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

10.2.5 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in Section 11.

10.2.6 At the annual general examination referred to in 10.1.1, the requirements of*Pt 1, Ch 3, 2.3 Machinery* are to be complied with.

10.2.7 For gas and crude oil burning systems, remote and/or automatic controls are to be examined and tested. Ventilating systems for ducts and machinery spaces are to be examined, tested and proven satisfactory.

■ *Section 11* Steam pipes

11.1 Frequency of surveys

11.1.1 Saturated steam pipes, and superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450°C, are to be surveyed 10 years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450°C are to be surveyed five years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.3 At 10 years from the date of build (or installation) and thereafter at five-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure.

11.2 Scope of surveys

11.2.1 At each survey, a selected number of main steam pipes, also of auxiliary steam pipes, which:

(a) are over 76 mm external diameter;
(b) supply steam for essential services at sea; and
(c) have bolted joints,

are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as is practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

11.2.2 Where main and/or auxiliary steam pipes of the category described in 11.2.1(a) and (b) have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, and the welds examined and, if considered necessary by the Surveyor, crack-detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

11.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 11.1, to be included in the pipes selected for examination and testing, as defined in 11.2.1. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to be satisfied of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and, if the Surveyor considers it necessary, a sample pipe is to be removed for examination.

11.2.4 At the surveys specified in*Pt 1, Ch 3, 11.1 Frequency of surveys*, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, also closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

11.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, the Classification Committee will be prepared to consider postponement of the survey, either wholly or in part.

Section 12
Screwshafts, tube shafts and propellers

12.1 Frequency of surveys

12.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

12.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.4 All other shafts not covered by 12.1.1 to 12.1.3 are to be surveyed at intervals of 21/2 years.

12.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

12.1.6 Directional propeller and podded propulsion units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

12.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years, provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

12.1.8 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years.

12.2 Normal surveys

12.2.1 For self-propelled disconnectable units, screwshaft surveys held afloat at five-yearly intervals are to comply with the following:

(a) Measurement of bearing weardown.
(b) Verification of tightness of oil glands.
(c) Examination of propeller and fastenings.
(d) Verification on board of documentation of stern tube lubricating oil analysis carried out at regular intervals not exceeding six months. Each analysis, to be carried out on oil samples taken under service conditions and representative of oil within the stern tube, is to include the following minimum parameters:
    (i) Water content.
    (ii) Chloride content.
    (iii) Bearing material and metal particle content.
    (iv) Oil ageing (resistance to oxidation).
(e) Verification of records of oil consumption and bearing temperatures.

12.2.2 Directional propeller and podded propulsion units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.2.3 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.2.4 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. See *Pt 5, Ch 9, 6.3 Propulsion shafting 6.3.8* of the Rules for Ships.

12.3 Complete surveys

12.3.1 If a self-propelled unit enters dry dock any time after five years from the previous dry-docking, date of build or date of commissioning, as applicable, a complete screwshaft survey is to be held.

12.3.2 All screwshafts are to be withdrawn for examination by LR's Surveyors. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment, at least the forward one third of the shaft cone is to be examined with the key removed.

Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear.

12.3.3 Directional propeller and azimuth thruster units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.3.4 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

12.3.5 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.3.6 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. See *Pt 5, Ch 9, 6.3 Propulsion shafting 6.3.8* of the Rules for Ships.

12.4 Screwshaft Condition Monitoring (SCM)

12.4.1 Monitoring records are to be reviewed at annual survey for all units assigned the ShipRight descriptive note SCM (Screwshaft Condition Monitoring). The records that are to be maintained for oil and water lubricated bearings are detailed in the following sections.

12.4.2 Oil lubricated bearing records are to be available on board that include the following:

(a) Lubricating oil analysis is to be carried out regularly at intervals not exceeding six months. Each analysis is to include the following minimum parameters:

  (i) Water content;
  (ii) Chloride content;
  (iii) Bearing material and metal particles content;
  (iv) Oil ageing (resistance to oxidation);
  (v) Minimum testing to include Viscosity and Total Acid Number (TAN).

  Note: Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(b) Oil consumption
(c) Bearing temperatures

12.4.3 Water lubricated bearing records are to be available on board that include the following:

(a) A record of variations in the flow rate of lubricating water.
(b) A record of variation in the shaft power transmission.
(c) Wear monitoring records for the sternbush.
(d) For open loop systems the records from equipment for continuous monitoring of water sediment or turbidity are to be provided if requested by the attending surveyor, alternatively if a LR approved extractive sampling and testing procedure is used then the applicable records are to be made available if requested. Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.
(e) Where a closed cycle water system is used, the pumping and water filtration systems are to be considered part of the continuous survey cycle and are to be subject to a Periodical Survey. Water analysis is to be carried out regularly at intervals not exceeding six months. Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube. Analysis results are to be retained on board and made available to LR on request. The analysis is to include the following parameters:

  (i) Chloride content
  (ii) Bearing material and metal particles content.

12.4.4 For maintenance of the descriptive note **SCM**, the records of all data collected in*Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM)* and *Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM)* are to be retained on board and audited by LR annually.

12.4.5 Where the requirements for the descriptive note SCM have been complied with, the screwshaft need not be withdrawn at surveys as required by 12.3.2, provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method or an alternative approved means for shafts with a protective liner or coating (*see Pt 5, Ch 6, 4.1 Screwshaft Condition Monitoring (SCM) 4.1.3* of the *Rules and Regulations for the*

Classification of Ships). The remaining requirements of *Pt 1, Ch 3, 12.3 Complete surveys* are to be complied with. Where the Attending Surveyor considers that the data presented is not sufficient to determine the condition of the shaft, the shaft may be required to be withdrawn in accordance with *Pt 1, Ch 3, 12.3 Complete surveys*. For water lubricated bearings, the screwshaft is to be withdrawn for examination, as *Pt 1, Ch 3, 12.3 Complete surveys*, when the unit reaches 18 years from the date of build or the third Special Survey, whichever comes first.

12.5 Modified Survey

12.5.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in *Pt 1, Ch 3, 12.1 Frequency of surveys*, provided that they are fitted with oil lubricated bearings and approved oil glands, and also for those in 12.1.2 and 12.1.3.

12.5.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller, a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts, including the propeller connection to the shaft, are to be examined as far as possible. Weardown is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

12.5.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

12.6 Extension of Intervals of Surveys

Consideration can be given at the discretion of the Classification Committee to extend the intervals between surveys. This will be based on:

(a) A satisfactory diver’s/ROV external examination of the shaft bearing and outboard seal area including weardown check as far as is possible.
(b) Internal examination of the shaft area (inboard seals) in propulsion room(s).
(c) Confirmation of satisfactory lubricating oil records (oil loss rate, contamination).
(d) Shaft seal elements are examined/replaced in accordance with seal’s manufacturer’s recommendations.

12.7 Special cases

12.7.1 The Classification Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 13*
Drilling plant facility

13.1 Frequency of surveys

13.1.1 Drilling units having a **DRILL** notation in accordance with *Pt 3, Ch 7 Drilling Plant Facility* are to be surveyed annually in accordance with the requirements of 2.7. A Special Survey in accordance with the requirements of *Pt 1, Ch 3, 13.2 Scope of surveys* is to be held at intervals not exceeding five years.

13.2 Scope of surveys

13.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the drilling plant facility:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their controls.
- Bulk storage.
- Choke manifold and associated valves.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick hoisting, rotation and pipe handling equipment.

- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.

13.2.2 Pressure vessels forming part of the drilling plant facility are to be examined in accordance with the requirements of *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*, see also *Pt 1, Ch 3, 2.5 Production and oil storage units* and *Pt 1, Ch 3, 2.7 Drilling units*.

13.2.3 Piping systems for mud, cement and other systems subject to considerable erosion are to be examined for leaks and corrosion.

13.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with *Pt 1, Ch 3, 16 Safety and communication systems and hazardous areas*.

■ *Section 14*
Process plant facility

14.1 Frequency of surveys

14.1.1 Production and oil storage units having a **PPF** notation in accordance with *Pt 3, Ch 8 Process Plant Facility* are to be surveyed annually in accordance with the requirements of 2.5 and 2.7. A Special Survey in accordance with the requirements of 14.2 is to be held at intervals not exceeding five years.

14.2 Scope of surveys

14.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the process plant facility:

- Major equipment of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.

14.2.2 Pressure vessels forming part of the process plant facility are to be examined in accordance with the requirements of *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*, see also *Pt 1, Ch 3, 2.5 Production and oil storage units* and *Pt 1, Ch 3, 2.7 Drilling units*.

14.2.3 Piping systems and valves are to be examined for leaks and corrosion.

14.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with *Pt 1, Ch 3, 16 Safety and communication systems and hazardous areas*.

■ *Section 15*
Riser systems

15.1 Surveys – General

15.1.1 For units having a **PRS** notation in accordance with *Pt 3, Ch 12 Riser Systems*, Riser Systems are to be surveyed as per a planned survey schedule agreed between the Owners and LR. This schedule should cover the extent, level and method of systematic examination of critical components of the system.

15.1.2 Extent and frequency of thickness measurements of components and areas where deterioration may be expected due to corrosion are to be included in the above schedule.

15.1.3 An agreed schedule for periodic surveys should be capable of determining condition of riser pipe structure and associated critical components, such as any cladding, bend stiffeners, end connectors, subsea buoyant supporting vessels, subsea valves, anti-corrosive coatings, etc.

15.1.4 This schedule should also include examination and testing of the riser system under working conditions at each Annual Survey.

15.1.5 Emergency shut-down systems with associated communication system, telemetry or instrumentation, pressure relief systems, systems for leak detection and protection against pressure surges are to be tested at each Annual Survey as per agreed procedures.

■ *Section 16*
Safety and communication systems and hazardous areas

16.1 Frequency of surveys

16.1.1 Safety and communication systems and hazardous areas are to be surveyed annually in accordance with the requirements of 2.4. A Special Survey of safety and communication systems and hazardous areas in accordance with the requirements of *Pt 1, Ch 3, 16.2 Scope of surveys* is to be held at intervals not exceeding five years.

16.2 Scope of surveys

16.2.1 The Surveyor is to examine and be satisfied as to the efficient condition of the following systems as required by *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*:

(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Protection system against flooding, including:
  (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
  (ii) Bilge level detection and alarm systems on column-stabilised units and in machinery spaces on surface type units.
  (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.
(g) Fire detection and extinguishing apparatus.

16.2.2 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

16.2.3 Enclosed hazardous areas such as those containing open active mud tanks, shale shakers, degassers and desanders are to be examined and doors and closures in boundary bulkheads verified as effective. Ventilating systems including duct work, fans, intake and exhaust locations for enclosed restricted areas are to be examined, tested and proven satisfactory. Ventilating-air alarm systems are to be proven satisfactory. In hazardous areas electric lighting, electrical fixtures, and instrumentation are to be examined, proven satisfactory and verified as explosion-proof or intrinsically safe. A complete survey of electrical installations is to be carried out in accordance with Section 9. Electrical motors are to be examined, including closed-loop ventilating systems for large d.c. motors. Automatic power disconnect to motors in case of loss of ventilating air is to be proved satisfactory.

16.2.4 Piping systems for process plant and other systems in hazardous areas are to be checked for leaks, corrosion, and the safe operation of valves. Piping systems are to be tested when required by the Surveyor.

16.2.5 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

Section 17
Pressure vessels for process and drilling plant

17.1 Frequency of surveys

17.1.1 All pressure vessels are to be examined at the first Annual Survey after commissioning and subsequently at each Special Survey, see*Pt 1, Ch 3, 2.3 Machinery*.

17.2 Scope of surveys

17.2.1 At the surveys described in 17.1, all pressure vessels are to be examined internally and externally. Principal mountings, supports and attachments to pressure vessels are to be examined, see also 17.2.4.

17.2.2 Where pressure vessels are so constructed that internal inspection is prevented by normal means, agreed tests are to be carried out to the satisfaction of the Surveyor.

17.2.3 Where, due to operational requirements, it is not possible to present all pressure vessels for inspection at the first Annual Survey, a sufficient number of pressure vessels from each system is to be examined, as agreed with the Surveyor, in order to establish the extent of corrosion and general condition of the system. The Owner's proposals for the inspection of the remaining pressure vessels are to be included in the Owner's planned maintenance and inspection procedure, as required by *Pt 1, Ch 3, 1.6 Planned survey programme*.

17.2.4 Selected pressure safety valves are to be bench tested in accordance with the requirements of*Pt 1, Ch 3, 2.5 Production and oil storage units*. The Surveyor is to confirm that all pressure safety valves forming part of the process and drilling plant facility are examined and bench tested within each special survey cycle.

Section 18
Inert gas systems

18.1 Frequency of surveys

18.1.1 Inert gas systems installed on board units intended for the storage of oil in bulk storage tanks are to be surveyed annually in accordance with the requirements of 2.6. A Special Survey of the inert gas system, in accordance with the requirements of 18.2, is to be held at intervals not exceeding five years.

18.2 Scope of surveys

18.2.1 At each Special Survey of the inert gas system, the inert gas generator, scrubber and blower are to be opened out as considered necessary and examined. Gas distribution lines and shut-off valves, including soot blower interlocking devices, as well as interlocking features and positive isolation for tank isolation are to be examined as considered necessary. The deck seal and non-return valve are to be examined. Cooling water systems including the effluent piping and overboard discharge from the scrubbers are to be examined. All automatic shut-down devices and alarms are to be tested. The complete installation is to be tested under working conditions on completion of survey.

18.2.2 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the inert gas systems may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery is to be examined each year.

18.2.3 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

18.2.4 *See Pt 1, Ch 3, 21.3 Annual Surveys – General Requirements for Fuel Systems* and*Pt 1, Ch 3, 21.8 Complete Surveys – General requirements* for inert gas systems on units with natural gas fuel installations.

■ *Section 19*
Classification of units not built under survey

19.1 General

19.1.1 When classification is desired for a unit not built under the supervision of LR's Surveyors, application should be made to the Classification Committee in writing.

19.1.2 Periodical Surveys of such units, when classed, are subsequently to be held, as in the case of units built under survey.

19.1.3 Where classification is desired for a unit which is classed by another recognised Society, special consideration will be given to the scope of the survey.

19.2 Hull and equipment

19.2.1 Plans showing the main scantlings and arrangements of the actual unit, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the main hull/structure, including midship section, longitudinal and transverse sections, columns, decks, pontoons, bracings, legs and footings and such other plans as may be requested. If the class notation **DRILL** or **PPF** is to be assigned in accordance with *Pt 3, Ch 7 Drilling Plant Facility* or *Pt 3, Ch 8 Process Plant Facility* respectively, plans and documentation covering the major structures of the plant are to be submitted as may be requested.

19.2.2 If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the unit. The unit's Operations Manual is also to be submitted, see *Pt 3, Ch 1, 3 Operations manual*.

19.2.3 Particulars of the process of manufacture, material grades and the testing of the material of construction are to be supplied.

19.2.4 In all cases, the full requirements of *Pt 1, Ch 3, 5 Special Survey – Hull requirements* are to be carried out as applicable. Units of recent construction will receive special consideration.

19.2.5 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Loading instruments, where required, are to be in accordance with the Rules, see *Pt 1, Ch 2, 1.4 General* as applicable.

19.2.6 Safety and communication systems are to be verified in accordance with *Pt 1, Ch 3, 16 Safety and communication systems and hazardous areas*, see also *Pt 1, Ch 3, 1.1 Frequency of surveys*.

19.2.7 When the full survey requirements indicated in 19.2.4 and 19.2.5 cannot be completed at one time, the Classification Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

19.3 Machinery

19.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings are to be supplied:

- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Pumping arrangements at the forward and after ends of units with crude oil bulk storage tanks and drainage of cofferdams and pump-rooms.
- General arrangement of crude oil storage piping in tanks and on deck.
- Piping arrangements for bulk oil storage (F.P. 60°C or above, closed-cup test).
- Bilge, ballast and fuel oil pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of main steam pipes.
- Arrangement of fuel oil pipes and fittings at settling and service tanks.
- Arrangement of fuel oil and gas piping in connection with oil and gas burning installations.
- Fuel oil and bulk oil storage overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Fuel oil settling, service and other fuel oil tanks not forming part of the unit's structure.

- Boilers, superheaters and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied).
- Azimuth thrusters.
- Electrical circuits.
- Hazardous areas.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- General arrangement of crude oil storage tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc. Ventilation arrangements of storage tanks and/or ballast pump-rooms and other enclosed spaces which contain crude oil handling equipment.
- Safety and communication systems, see *Pt 3, Ch 1 General Requirements for Offshore Units*.
- Jacking arrangements on self-elevating units.

19.3.2 Plans additional to those detailed in 19.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification. If the class notation **DRILL** or **PPF** is to be assigned in accordance with *Pt 3, Ch 7 Drilling Plant Facility* or *Pt 3, Ch 8 Process Plant Facility* respectively, plans and documentation covering the plant are to be submitted as may be requested.

19.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

19.3.4 For new units and units which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older units, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Classification Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

19.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

19.3.6 Pressure vessels for process and drilling plant are to be examined as required for Special Surveys in *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant*.

19.3.7 The screwshaft is to be drawn and examined.

19.3.8 The steam pipes are to be examined and tested as required by Section 11.

19.3.9 The bilge, ballast and fuel oil pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

19.3.10 Oil and gas burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

19.3.11 The electrical equipment is to be examined as required at Complete Surveys in *Pt 1, Ch 3, 9 Electrical equipment*.

19.3.12 Where an inert gas system is fitted on units intended for the storage of oil in bulk having a flash point not exceeding 60°C, the requirements of *Pt 5, Ch 15, 7 Inert gas systems on Tankers of 8,000 tonnes DWT and above* of the Rules for Ships apply.

19.3.13 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor's satisfaction.

19.3.14 Safety and communication systems and hazardous areas are to be examined as required at Special Surveys in Section 16. The requirements of *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE* are to be complied with.

■ *Section 20* Laid-up machinery

20.1 Survey requirements

20.1.1 Main and/or auxiliary propulsion, main and auxiliary steering gear and jack-up machinery not in use when the installation is operating at a fixed location may not be subject to periodic surveys as required by Sections 2 to 19. The machinery may be retained on board in laid-up status as per manufacturers' recommendations. However, all overdue surveys and reactivation requirements are to be dealt with prior to recommissioning. The reactivation requirements will be advised by LR on request.

20.1.2 If laid-up machinery is required to be used when the unit is disconnected from its moorings in an emergency, the periodic maintenance and operation schedules are to be in accordance with the manufacturers' recommendations and specially agreed to by LR.

■ *Section 21* Natural Gas Fuel Installations

21.1 General

21.1.1 The requirements of *Pt 1, Ch 3, 6 Machinery Surveys – General requirements* Machinery surveys – *General requirements* are to be complied with, as applicable.

21.1.2 In addition to the survey requirements below, further survey requirements may be imposed; as identified during the risk assessment process, *see Pt 1, Ch 2, 3.6 Surveys for novel/complex systems*.

21.1.3 This Section provides requirements for the survey of natural gas fuel installations as defined in *Pt 1, Ch 3, 1.5 Definitions* (natural gas is hereinafter referred to as fuel).

21.1.4 The fuel installation is to be surveyed in working condition except at Special Survey where internal examination of some components will be required. *See Pt 1, Ch 3, 21.8 Complete Surveys – General requirements* and *Pt 1, Ch 3, 21.9 Complete Surveys – Natural gas fuelled consumers and other equipment*.

21.1.5 Annual Survey should be scheduled, if possible, to coincide with a bunkering operation to allow for verification of fuel storage tank level alarms and bunkering control, alert and safety systems under operational conditions. At annual survey physical testing of alarms and shutdowns is not required unless it is considered necessary by the attending surveyor. In any case records of the alarms are to be retained for the verification of the attending Surveyor.

21.1.6 The Intermediate Survey supplements the Annual Survey by testing the fuel bunkering system including automatic control, alert and safety systems to confirm satisfactory operation. The extent of the testing required for the Intermediate Survey may briefly interrupt the fuel installation and therefore unit operations and the survey are to be scheduled accordingly.

21.1.7 The extent of the testing required for Complete Surveys will normally be such that the full survey cannot be carried out with the fuel installation operating or loaded with fuel. Consequently, aspects of the survey should be coordinated to correspond with drydocking or another period when the system will be gas free. Completion of the survey requires verification of satisfactory condition of the installation at the normal operating temperatures and pressures so will normally be completed once the unit has been bunkered following reactivation of the system.

21.1.8 Prior to any internal inspection of fuel storage tanks, associated piping, fittings and equipment, etc., the respective items are to be made safe for access by means of isolating relevant valves, purging and gas-freeing the space.

21.1.9 Where an approved condition-monitoring system is employed for the fuel system and its constituent components, and the applicable Descriptive Note is assigned, the requirements of these regulations for opening up and internal examination may be waived where the condition of the equipment can be shown to be within agreed acceptable limits as detailed in *Pt 5, Ch 21 Requirements for Condition Monitoring Systems and Machinery Condition-Based Maintenance Systems* of the *Rules and Regulations for the Classification of Ships*.

21.1.10 The following documentation, as applicable, is to be available on board the unit:

(a) Relevant instruction and information such as loading limit curve information, bunkering procedures, cooling down procedures and fuel installation test and inspection procedures.
(b) Condition-Monitoring or Condition-Based Maintenance documentation as applicable.
(c) Test records for bunkering ESD systems.
(d) Records of crew tests/inspections of the fuel installation.

21.1.11 For Special Survey requirements for electrical equipment *see Pt 1, Ch 3, 9 Electrical equipment*.

21.2 Survey Following Repair

21.2.1 Following repair, independent fuel storage tanks of Type C are to be hydrostatically tested in accordance with the manufacturer's test and inspection instructions (normally at 1,25 times the approved maximum vapour pressure). Other types of fuel storage tank, such as membrane tanks, are to be tested in accordance with approved procedures provided by the fuel storage tank designers. After testing, suitable drying and consequent air-purging procedures are to be followed to return the tank to operational condition.

21.3 Annual Surveys – General Requirements for Fuel Systems

21.3.1 The Annual Survey is to be carried out with the fuel installation operational. Gas-freeing will not generally be necessary.

21.3.2 The unit's log and operational records for the fuel installation, covering the period from the previous survey, are to be examined. Any malfunction of the installation recorded in the log is to be investigated. It is to be verified that any repairs have been carried out to an acceptable standard and in accordance with the applicable Rules and Regulations.

21.3.3 Control, alert and safety systems are to be surveyed as follows:

(a) The control, alert and safety systems for the fuel storage tanks and processing system are to be verified in satisfactory condition by one or more of the following methods:
 (i) Comparison of read-outs from local and remote indicators.
 (ii) Consideration of read-outs with regard to the actual conditions.
 (iii) Examination of maintenance records with reference to the approved maintenance management system.
 (iv) Verification of calibration status of the measuring instruments.
(b) All control, alerts and safety systems are to be tested, where testing is not possible due to operational reasons simulated testing may be accepted by the attending Surveyor. Which are to include but are not limited to:
 (i) fuel storage tank and processing system high and low pressure
 (ii) fuel storage tank high and high-high level
 (iii) fuel storage tank overfill level
 (iv) fuel storage tank high temperature.
(c) Fuel leakage detection systems (temperature sensors and gas detection as applicable) are to be examined and tested in accordance with the manufacturer's instructions and calibrated using sample gas.
(d) The electrical installation, equipment and cables in areas which may contain flammable gas are to be examined in order to verify that they are in good condition and have been properly maintained. Bonding straps that are installed to control static electricity are to be visually examined.
(e) Alerts and safety systems associated with pressurised installations and any safety device associated with non-safe type electrical equipment that is protected by air-locks or pressurisation, are to be verified.

21.3.4 Fuel installations are to be surveyed as follows:

(a) Portable and/or fixed drip trays, or insulation providing protection in the event of fuel leakage, are to be examined.
(b) Components of the fuel installation fitted with insulation to provide protection against ice formation on are to be examined for satisfactory condition.
(c) Fuel piping, valves and fittings are to be generally examined, with particular attention to double-wall or ventilated ducting arrangements, expansion bellows, supports and vapour seals on insulated piping.

21.3.5 Inerting arrangements and associated alarms are to be verified as being in satisfactory condition, including the means for prevention of backflow of fuel vapour to the inert gas system.

21.3.6 Ventilation systems are to be surveyed as follows:

(a) Ventilation systems and air-locks including their alarm system are to be generally examined.

(b) Ventilation fans in hazardous areas are to be visually examined.
(c) For ventilated double-walled piping or ducting containing fuel piping within machinery spaces, exhaust fans and/or supply fans are to be examined to ensure that the air-flow is not impeded.
(d) Fuel piping and components associated with the fuel processing equipment are to be visually examined.

21.3.7 The closing devices for all air-intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses less than 10m from deck-mounted fuel storage tanks, are to be examined.

21.3.8 Venting arrangements, including protection screens if provided, for fuel storage tanks, inter-barrier spaces and tank hold spaces as applicable, are to be visually examined externally. The external condition of the fuel storage tank relief valves is to be verified and records of the last test of the opening/closing pressures are to be reviewed.

21.3.9 Means for draining the vent arrangements from fuel storage tank pressure relief valves and other system relief valves are to be examined to ensure that there is no liquid build-up that would impede effective operation, drain valves are to be checked as applicable.

21.3.10 Heating arrangements, if fitted, for steel structures in cofferdams and other spaces are to be verified in satisfactory condition.

21.3.11 All gas-tight bulkhead penetrations, including any gas-tight shaft seals, are to be visually examined.

21.4 Annual Surveys – Fuel Processing Equipment

21.4.1 The following fuel processing equipment is to be generally examined in working condition and operational parameters verified. Insulation, where fitted, need not be removed but any deterioration of insulation, or evidence of dampness which could lead to external corrosion of the vessels or their connections, is to be investigated:

(a) Heat exchangers and pressure vessels.
(b) Natural gas fuel heaters, vaporisers, masthead heaters.
(c) Heating arrangements, including provision for continuous heating and circulation of heating medium to prevent freezing during start up and when the fuel installation is not in use.
(d) Fuel piping and components associated with the fuel processing equipment.

21.4.2 Where the double wall or duct containing fuel piping is protected using a pressurised inert gas atmosphere the monitoring and maintenance of the inert atmosphere is to be confirmed in satisfactory condition.

21.4.3 The condition of the fuel isolation valve and double block and bleed arrangements for each consumer is to be examined with respect to:

(a) Containment to prevent fuel leakage from any valve arrangements installed within the machinery space.
(b) Connections to the inerting and venting arrangements.
(c) General examination to confirm that the valve arrangement and all associated fuel monitoring and control equipment are in satisfactory condition. The external examination is to be supplemented by a review of relevant operational, maintenance and service reports.

21.4.4 Where fuel processing equipment is located within an independent space that functions as containment in the event of a fuel spill (e.g. a tank connection space), the space is to be examined internally and externally to verify that the structure remains in a satisfactory condition to contain any potential leakage of fuel including any thermal isolation to protect surrounding structure from damage due to cryogenic leakage.

21.5 Annual Surveys – Fuel Storage

21.5.1 Areas in which fuel storage tanks are located (on and below deck) are to be examined for any changes to the arrangements within those areas that may affect the hazardous area rating.

21.5.2 For Type C pressurised fuel storage tanks the external surface of the fuel storage tank insulation is to be visually examined for cold spots to verify the condition of the insulation arrangements. This examination is to be carried out with the fuel storage tanks loaded. Ideally fuel storage tanks should be loaded to the maximum loading limit; examination of partially-filled fuel storage tanks may be accepted alongside a review of records of periodic cold spot examinations carried out by suitably trained and qualified crew.

21.5.3 The supporting structure is to be examined to confirm that the saddle arrangement remains in satisfactory condition in accordance with the approved design.

21.5.4 For vacuum-insulated fuel storage tanks, monitoring records are to be reviewed to confirm satisfactory maintenance of the vacuum. Any trends identifying a breakdown or loss of vacuum containment are to be investigated.

21.5.5 For Type B fuel storage tanks where the insulation arrangements are such that the insulation cannot be examined, the surrounding structures of wing tanks, double bottom tanks and cofferdams are to be visually examined for cold spots. This examination is to be carried out with the fuel storage tanks loaded. Ideally fuel storage tanks should be loaded to the maximum loading limit; examination of partially-filled fuel storage tanks may be accepted alongside a review of records of periodic cold spot examinations carried out by suitable trained and qualified crew.

21.5.6 For membrane fuel storage tanks the performance of the insulation arrangements is to be confirmed in accordance with approved procedures submitted by the containment designers.

21.6 Annual Survey - Fuel Bunkering System

21.6.1 The fuel-bunkering system, including manifold connections, isolation valves, bunker piping and linked Emergency Shut Down (ESD) system connection equipment (including cabling and connectors), are to be visually examined.

21.6.2 Bunkering operations are to be observed as far as possible; satisfactory condition of the bunkering control alert and safety system is to be verified. During annual survey it is not expected that ESD1 (stoppage of bunker transfer) or ESD2 (disconnection of bunker piping) will be operationally tested but records of maintenance and testing are to be reviewed. However, prior to starting the bunkering operation, it is expected that an ESD1 is tested with no LNG in the system (i.e. a dry test). Records of the testing are to be available during survey.

21.7 Intermediate Surveys

21.7.1 In addition to the requirements below, the requirements of *Pt 1, Ch 3, 21.1 General* to *Pt 1, Ch 3, 21.6 Annual Survey - Fuel Bunkering System* are to be complied with.

(a) Control, alert and safety systems for the bunkering system, fuel-containment systems and processing equipment, together with any associated shutdown and/or interlock, are to be tested under working conditions and, if necessary, recalibrated. Shutdown sequence and extent are to be verified against documented procedures where applicable. Such safety systems include but are not limited to:

   (i) Bunkering ESD system is to be tested, without fuel in the piping, to verify that ESD system operation will result in a closure of the isolation valves and a shutdown of machinery associated with bunkering operations. All ESD activations and outputs are to be tested including fuel storage tank overfill protection, bunkering isolation valve closure and automatic shutdown of machinery associated with bunkering operations.

   (ii) Fuel-processing equipment shutdown and closure of isolation valves resulting from:

- loss of the valve-actuating medium;
- loss of ventilation in fuel piping double wall /ventilated duct; or
- loss of pressure of inert gas in pressurised double-walled pipe arrangement.

   (iii) Fuel processing equipment shutdown and closure of isolation valves as a result of deviation in the fuel supply to engineroom from the normal operating conditions (temperature and pressure).

   (iv) Fuel installation shutdown as a result of gas detection.

   (v) Safety interlocks on fuel-processing equipment are to be examined and tested as necessary to confirm satisfactory condition.

(b) A General Examination within the areas deemed as hazardous, such as bunker stations, vent mast area, tank connection space and spaces adjacent to vent arrangements from the tank connection space (if applicable), to verify the electrical arrangements have been maintained satisfactorily for operation in a hazardous environment.

(c) Verification that piping and independent fuel storage tanks are electrically bonded to the hull.

21.7.2 Consideration will be given to simulated testing, provided that it is considered representative. Comprehensive maintenance records, including details of tests carried out in accordance with the fuel plant and instrumentation maintenance manuals may be presented for review. Acceptance of either simulated testing or maintenance records including reports of testing as described above is subject to the satisfaction of the attending Surveyor.

21.8 Complete Surveys – General requirements

21.8.1 The requirements of *Pt 1, Ch 3, 21.1 General* to *Pt 1, Ch 3, 21.7 Intermediate Surveys* are to be complied with.

21.8.2 The items covered by *Pt 1, Ch 3, 21.8 Complete Surveys – General requirements* to *Pt 1, Ch 3, 21.9 Complete Surveys – Natural gas fuelled consumers and other equipment 21.9.5* may, at the request of the Owner, be examined on a Continuous Survey basis provided the interval between examinations of each item does not exceed five years. Exceptions may be made to this requirement if Condition Based Maintenance arrangements have been agreed and maintained satisfactorily (*see Pt 1, Ch 3, 21.1 General 21.1.9*).

21.8.3 Except where alternative provisions are given below, all fuel storage tanks are to be examined externally and internally, particular attention being paid to the plating in way of supports of securing arrangements for independent tanks, pipe connections, also to sealing arrangements in way of the deck penetrations. Insulation is to be removed as required.

21.8.4 Provided that the structural examination is satisfactory, that the gas detection systems have been found to be in satisfactory condition, routine on board checks and maintenance records are satisfactory and that the voyage records have not shown any abnormal operation, fuel storage tanks will not require hydrostatic testing (except as required by *Pt 1, Ch 3, 21.8 Complete Surveys – General requirements*.

21.8.5 The non-destructive testing (NDT) of independent fuel storage tanks is to supplement visual inspection with particular attention to be given to the integrity of the main structural members, tank shell and highly-stressed parts, including welded connections as deemed necessary by the Surveyor. The following items are considered as highly-stressed parts:

- structure in way of tank supports and anti-rolling/anti-pitching devices,
- web frames or stiffening rings,
- swash bulkhead boundaries,
- dome and stump connections to tank shell,
- foundations for pumps, towers, ladders, etc.,
- pipe connections.

21.8.6 The NDT testing requirements for different types of independent fuel storage tanks are detailed below:

(a) For independent fuel storage tanks of Type B, the extent of non-destructive testing is to be given in the test schedule specially prepared for the tank design. The Owner is to submit proposals for the extent of non-destructive testing of the fuel storage tanks in advance of the survey.

(b) For vacuum-insulated independent fuel storage tanks of Type C vacuum monitoring is accepted as a demonstration of the internal integrity of the tank. This is subject to verification that the monitoring equipment is being maintained, operated and calibrated in a satisfactory condition. There is no further requirement for internal examination and testing of these tanks. The tank support arrangements are to be visually examined; non-destructive testing may be required if the condition raises doubt as to the structural integrity.

(c) For non-vacuum insulated independent fuel storage tanks of Type C non-destructive testing is required on the plating in way of supports and also over selected lengths of welds. Where such testing raises doubt as to the structural integrity, further testing is to be carried out in accordance with the requirements of the manufacturer's test and inspection instructions for hydraulic testing (normally at 1,25 times the approved maximum vapour pressure). Alternatively, consideration will be given to pneumatic testing under special circumstances, provided full details are submitted for approval.

(d) At each alternate Complete Survey (i.e. at 10 year intervals); non-vacuum insulated independent fuel storage tanks of Type C are to be either:

    (i) Hydrostatically or hydro-pneumatically tested to not less than 1,25 times MARVS in accordance with the requirements of the manufacturer's test and inspection instructions. The requirements for non-destructive testing in 21.8.5 are to be carried out following this test as required by the Surveyor.

    Or:

    (ii) Subject to a thorough, planned, non-destructive testing. This testing is to be carried out in accordance with a test schedule specially prepared for the tank design. If a special programme does not exist, the following should be tested:

- structure in way of tank supports and anti-rolling/anti-pitching devices;
- stiffening rings;
- Y-connections between tank shell and a longitudinal bulkhead of bi-lobe tanks;
- swash bulkhead boundaries if applicable;
- dome and sump connections to the tank shell if applicable;
- pipe connections.

At least 10 per cent of the length of the welded connections in each of the above-mentioned areas is to be tested. This testing is to be carried out internally and externally as applicable. Insulation is to be removed as necessary for the required non-destructive testing.

21.8.7 Membrane fuel storage tank surveys are to be carried out in accordance with approved testing procedures provided by the containment designers.

21.8.8 Fuel storage tank pipe connections and fittings are to be examined, and all valves and cocks in direct communication with the interiors of the tanks are to be opened out for inspection and the connection pipes are to be examined internally, so far as practicable. Special attention is to be paid to the fuel storage tank master isolation valve(s); the valve seat is to be visually examined and the valve tested at the maximum working pressure of the fuel storage tank prior to re-commissioning the fuel system.

21.8.9 Relief valves are to be surveyed as follows:

(a) The pressure relief valves for the fuel storage tanks are to be opened for examination, adjusted to the correct operating pressure as indicated in *Pt 1, Ch 3, 21.8 Complete Surveys – General requirements*, function-tested, and sealed. If the tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced. Valves may be removed from the tank for the purpose of making this adjustment under pressure of air or other suitable gas. If valves are removed, the tank and fuel piping downstream of the tank isolation valves are to be gas-freed and inerted.

(b) Valves are to lift at a pressure not more than the percentage given below, above the maximum vapour pressure for which the tanks have been approved:

- For 0 to 1,5 bar, 10 per cent.
- For 1,5 to 3,0 bar, 6 per cent.
- For pressures exceeding 3,0 bar, 3 per cent.

(c) Where a detailed record of continuous overhaul and retesting of individually-identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since the previous Complete Survey.

(d) Relief valves on fuel piping are to have their pressure settings checked. The valves may be removed from the piping for this purpose. At the Surveyor's discretion a sample of each size and type of valve may be opened for examination and testing.

21.8.10 All fuel pumps, booster pumps and vapour pumps are to be opened out for examination. Where applicable, pumping systems for inter-barrier spaces are to be checked and verified to be in satisfactory condition.

21.8.11 Piping for the fuel processing system including valves, actuators and compensators is to be opened for examination. Insulation may need to be removed, as deemed necessary, to ascertain the condition of the piping. If any doubt exists regarding the integrity of the piping based upon visual examination then, where deemed necessary by the Surveyor, a pressure test at 1,25 times MARVS of the piping is to be carried out. The complete piping systems are to be tested for leaks after re-assembly.

21.8.12 Equipment for the production of inert gas is to be examined and shown to be in satisfactory condition, operating within the gas specification limits. Piping, valves, etc., for the distribution of the inert gas are to be generally examined. Pressure vessels for the storage of inert gas are to be examined internally and externally and the securing arrangements are to be specially examined. Pressure relief valves are to be demonstrated to be in satisfactory condition. Liquid nitrogen storage vessels are to be examined, so far as practicable, and all control equipment, alarms and safety devices are to be verified as operational.

21.8.13 Gastight bulkhead shaft seals are to be opened out so that the sealing arrangements may be checked.

21.8.14 Any sea connections associated with the fuel handling equipment are to be opened out when the unit is in dry dock.

21.8.15 Where an approved condition-monitoring system or condition-based maintenance system is in place, the requirements for opening up of equipment may be reduced accordingly where the condition of the equipment can be shown to be within agreed acceptable limits as detailed in*Pt 5, Ch 21 Requirements for Condition Monitoring Systems and Machinery Condition-Based Maintenance Systems* of the *Rules and Regulations for the Classification of Ships*.

21.8.16 Testing of the tank connection space and cofferdam leakage-detection arrangement (temperature sensors and gas detectors) is to be carried out.

21.8.17 An electrical insulation resistance test of the circuits terminating in, or passing through, hazardous areas, is to be carried out. If the unit is not in a gas-free condition, the results of previously recorded test readings may be accepted together with a review of the on-board monitoring of the earth loop impedance of relevant circuits.

21.9 Complete Surveys – Natural gas fuelled consumers and other equipment

21.9.1 Heat exchangers associated with the fuel installation are to be opened out and examined as follows:

(a) The water end covers of evaporators are to be removed for examination of the tubes, tube plates and covers.

(b) Heating medium pumps, including standby pump(s) which may be used on other services, are to be opened out for examination.

(c) Where a pressure vessel is insulated, sufficient insulation is to be removed, especially in way of connections and supports, to enable the vessel's condition to be ascertained.

Note this refers to external insulation, not additional insulation that may be installed in the annular space of a vacuum insulated tank.

(d) Insulated piping is to have sufficient insulation removed to enable its condition to be ascertained. Vapour seals are to be specially examined for their condition. Vacuum-insulated piping is to be visually examined and records of maintenance and vacuum monitoring are to be reviewed.

21.9.2 The steam side of steam heaters is to be hydraulically tested to 1,5 times the design pressure.

21.9.3 Fuel pipe ducts or casings are to be generally examined and the exhaust or inerting arrangements are to be verified.

21.9.4 All alarms associated with the natural gas burning systems are to be verified; including, but not limited to, main and auxiliary engines, boilers, incinerators and gas combustion units.

21.9.5 The satisfactory condition of all pressure relief valves and/or safety discs throughout the installation is to be verified.

■

Appendix 1 Notations

Table 3.22.1 Type Notations

Type Notations:		
Floating offshore installations:	**Mobile offshore units:**	**Buoys and single point moorings:**
Floating Production Unit	Accommodation unit	Mooring buoy
Floating Production, Storage and Offloading Unit	Mobile offshore drilling unit	Single-point mooring buoy
Floating Storage Offloading Unit	Crane unit	Tanker loading terminal
	Diving support unit	Mooring tower
	Support unit	Articulated mooring tower
	Multi-purpose support unit	
	Pipe laying unit	
	Drill ship	
	Fire-fighting unit 1	
	Fire-fighting unit 2	
	Fire-fighting unit 3	
	MainWIND	
	Liftboat	
Character symbols:		
Symbol	**Description**	**Further information**

OI	For a unit operating at a fixed location.	*Pt 1, Ch 2, 1.1 Application 1.1.2*, *Pt 1, Ch 2, 1.2 Floating offshore installations at a fixed location 1.2.1*,1.2.5 . *Pt 10, Ch 1, 1.2 Definitions 1.2.5* and *Pt 10, Ch 1, 1.3 Application of transit conditions 1.3.1*.
OU	For a mobile unit transiting between operational locations.	*Pt 1, Ch 2, 1.1 Application 1.1.2*, *Pt 1, Ch 2, 1.3 Mobile offshore units 1.3.1*.
✠	Assigned to units built to LR's rules.	
✠̄	Assigned to units built to other IACS society's rules and then classed with LR.	
✠̇	Assigned to units built to LR's class but using plans from another IACS society.	
100	Assigned to units operating at sea.	
A	Assigned to units which will be maintained in good and efficient condition.	
1	Assigned to units either having: a) anchoring and/or mooring equipment in good and efficient condition b) anchoring and/or mooring equipment in good and efficient condition suitable for a particular service c) Dynamic positioning system replacing the need for anchoring and/or mooring equipment.	
(1)	Assigned to self propelled floating offshore installations which are disconnectable in order to avoid severe storms or hazards.	*Pt 1, Ch 2, 3.8 Notice of surveys 3.8.2* *Pt 1, Ch 3, 3.2 Intermediate Surveys 3.2.6* and *Pt 1, Ch 3, 5.3 Examination and testing 5.3.30* *Pt 4, Ch 9 Anchoring and Towing Equipment* *Pt 10, Ch 1, 1.3 Application of transit conditions 1.3.2*
T	Assigned to floating offshore installations which have anchoring, mooring or linking equipment in good and efficient condition	*Pt 3, Ch 10 Positional Mooring Systems*
N	Assigned to units which do not require anchoring and mooring equipment to be fitted	*Pt 4, Ch 9 Anchoring and Towing Equipment*
* For classification purposes 1 and either T or N are to be assigned to a unit.		
Class Notations:		
Notation:	**Description**	**Further information**
✠ **OMC**	Assigned to non-propelled units whose remaining machinery has been built to LR's Rules	
✠̇ **OMC**	Assigned to non-propelled units whose remaining machinery has been built to other IACS society's rules and then classed with LR.	
(✠)**OMC**	Assigned to non-propelled units where some remaining machinery has not been built to LR's Rules.	
✠ **LMC**	Assigned to propelled units whose machinery has been built to LR's Rules.	

✠ LMC	Assigned to propelled units whose machinery has been built to other IACS society's rules and then classed with LR.	
(✠)LMC	Assigned to propelled units where some remaining machinery has not been built to LR's Rules.	
IGS	Assigned to units having the facility to store crude oil and are fitted with an approved system for producing gas for inerting the crude oil storage tanks.	*Pt 1, Ch 3, 18 Inert gas systems*
UMS	Assigned where the unit can operate with unattended machinery spaces.	*Pt 6, Ch 1, 4 Unattended machinery space(s) – UMS notation* *Pt 6, Ch 1, 7.2 Unattended machinery space operation – UMS notation* *Pt 7, Ch 1 Safety and Communication Systems* *Pt 6, Ch 1, 4 Unattended machinery space(s) - UMS notation – Rules and Regulations for the Classification of Ships, July 2016*
CCS	Assigned where the unit can operate machinery from a centralised control system.	*Pt 6, Ch 1, 5 Machinery operated from a centralised control station – CCS notation* *Pt 6, Ch 1, 7.3 Operation from a centralised control station – CCS notation* *Pt 7, Ch 1 Safety and Communication Systems* *Pt 6, Ch 1, 5 Machinery operated from a centralised control station - CCS notation – Rules and Regulations for the Classification of Ships, July 2016*
ICC	Assigned where the unit's operational functions have an integrated computer control	*Pt 6, Ch 1, 6 Integrated computer control – ICC notation* *Pt 6, Ch 1, 6 Integrated computer control - ICC notation– Rules and Regulations for the Classification of Ships, July 2016*
IP	Assigned to units where the machinery arrangements and control systems necessary for operating essential machinery is from a centralised control system.	*Pt 5, Ch 18 Integrated Propulsion Systems - Rules and Regulations for the Classification of Ships, July 2016*
✠ Lloyd's RMC(LG)	Mandatory to units when reliquefaction and/or refrigeration equipment is fitted	*Pt 11, Ch 1, 1.6 Class notations and descriptive notes 1.6.3*
CSR	Assigned to floating offshore installations having previously been built as double hull oil tankers to IACS's Common Structural Rules	Generally indicates a hull fatigue life of 25 years from date of build.
Restrictions:	**Meaning:**	
Service area	An additional notation assigned indicating the unit may only operate at one particular point or area.	
Special features:		
Notation	**Description**	**See also**

PPF	Process plant facility. Assigned to floating offshore installations where facilities are built to LR's Rules or a recognised code and standard accepted by LR.	*Pt 1, Ch 2, 1.2 Floating offshore installations at a fixed location 1.2.1* *Pt 1, Ch 3, 1.6 Planned survey programme 1.6.3* , *Pt 1, Ch 3, 2.5 Production and oil storage units 2.5.5* , *Pt 1, Ch 3, 5.3 Examination and testing 5.3.26* , *Pt 1, Ch 3, 14 Process plant facility* , *Pt 1, Ch 3, 19.2 Hull and equipment* and *Pt 1, Ch 3, 19.3 Machinery 19.3.2*. *Pt 3, Ch 3, 1.2 Class notations 1.2.5* and *Pt 3, Ch 3, 1.2 Class notations 1.2.6* *Pt 3, Ch 8 Process Plant Facility* *Pt 4, Ch 4, 1.10 Topside structure 1.10.4* *Pt 10, Ch 1, 1.1 Application 1.1.10*
OIWS	Offshore in-water survey. Assigned when a unit does not intend to drydock during its normal service life.	*Pt 1, Ch 3, 4 Docking Surveys and In-water Surveys – Hull and machinery requirements* *Pt 3, Ch 1 General Requirements for Offshore Units* *Pt 4, Ch 1, 4.5 Plans to be supplied to the unit 4.5.2* *Pt 4, Ch 10, 2.1 General 2.1.2* *Pt 8, Ch 1 General Requirements for Corrosion Control*
LI	Loading instrument. Generally assigned to surface type units. Mandatory for such units over 65 m ensuring the Master has information that unacceptable stresses are not being placed on the unit whilst loading or off-loading.	*Pt 3, Ch 4 Longitudinal Strength - Rules and Regulations for the Classification of Ships, July 2016*
DP (CM)	Assigned where the unit is fitted with dynamic positioning arrangements and is fitted with centralised remote controls for position keeping	*Pt 3, Ch 9 Dynamic Positioning Systems* *Pt 7, Ch 4, 2 Class notation DP(CM) – Rules and Regulations for the Classification of Ships, July 2016*
DP (AM)	Assigned where the unit is fitted with dynamic positioning arrangements and is fitted with automatic main and manual standby controls for position keeping	*Pt 3, Ch 9 Dynamic Positioning Systems* *Pt 6, Ch 2, 15.3 Thruster systems for dynamic positioning* *Pt 7, Ch 4, 3 Class notation DP(AM) – Rules and Regulations for the Classification of Ships, July 2016*
DP (AA)	Assigned where the unit is fitted with dynamic positioning arrangements and is fitted with automatic main and automatic standby controls for position keeping	*Pt 3, Ch 9 Dynamic Positioning Systems* *Pt 7, Ch 4, 4 Class notation DP(AA) – Rules and Regulations for the Classification of Ships, July 2016*
DP (AAA)	Assigned where the unit is fitted with dynamic positioning arrangements and is fitted with automatic main and automatic standby controls together with an additional/ emergency automatic control unit for position keeping	*Pt 3, Ch 9 Dynamic Positioning Systems* *Pt 7, Ch 4, 5 Class notation DP(AAA) – Rules and Regulations for the Classification of Ships, July 2016*

PCR	Performance Capability Rating. Additional to a DP notation. The rating indicates the calculated percentage of time that a unit is capable of holding position under a standard set of conditions	*Pt 3, Ch 9 Dynamic Positioning Systems* *Pt 7, Ch 4, 6 Performance Capability Rating (PCR) – Rules and Regulations for the Classification of Ships, July 2016*
ECO	Assigned when the unit will implement and maintain operational pollution measures	*Pt 7, Ch 11 Arrangements and Equipment for Environmental Protection (ECO Class Notation) – Rules and Regulations for the Classification of Ships, July 2016*
ECO (TOC)	Assigned when the unit, transferring from another IACS Society, will implement and maintain operational pollution measures	*Pt 7, Ch 11 Arrangements and Equipment for Environmental Protection (ECO Class Notation) – Rules and Regulations for the Classification of Ships, July 2016*
CAV	Assigned when the unit is classed on the basis that LR has accepted performance standards as the basis for design and construction and will be subject to verification by LR once in service in accordance with local regulations where the unit is based.	Part 1 Chapter 2 Section 1.2.3 *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*
DRILL	Drilling plant facility. Assigned where facilities have are constructed, installed and tested by LR or a recognised code and standard accepted by LR.	*Pt 1, Ch 3, 1.6 Planned survey programme 1.6.3*, *Pt 1, Ch 3, 2.7 Drilling units 2.7.1*, *Pt 1, Ch 3, 5.3 Examination and testing 5.3.25*, *Pt 1, Ch 3, 13 Drilling plant facility*, *Pt 1, Ch 3, 19.2 Hull and equipment*, *Pt 1, Ch 3, 19.3 Machinery 19.3.2* *Pt 3, Ch 2 Drilling Units* *Pt 3, Ch 3, 1.2 Class notations 1.2.8* & *Pt 3, Ch 3, 1.2 Class notations 1.2.9* *Pt 3, Ch 7 Drilling Plant Facility* *Pt 4, Ch 4, 1.10 Topside structure 1.10.5* *Pt 4, Ch 6, 1.1 General 1.1.13* *Pt 10, Ch 1, 1.1 Application 1.1.11*
ShipRight SDA, RBA, FDA or CM	A notation indicating one or more of LR's ShipRight procedures have been satisfactorily followed.	ShipRight procedures *Pt 4, Ch 1, 4.6 Model test specifications and reporting* *Pt 10, Ch 1, 5.1 General 5.1.4*, *Pt 10, Ch 1, 6.1 General 6.1.4* and *Pt 10, Ch 1, 6.1 General 6.1.6*
DROPS	Assigned where risks to personnel are continuously addressed in so far as they affect the objectives of classification.	*Pt 3, Ch 7, 10 Risks to personnel from dropped objects*
PRS	Product riser system. Assigned where a unit is connected to a product riser complying with recognised codes and standards accepted by LR	*Pt 1, Ch 3, 1.6 Planned survey programme 1.6.6*, *Pt 1, Ch 3, 15 Riser systems*, *Pt 3, Ch 8, 9 Riser systems* *Pt 3, Ch 12 Riser Systems* *Pt 3, Ch 13, 1.4 Class notations 1.4.7* and *Pt 3, Ch 13, 2.3 Subsea buoyant vessels 2.3.1* *Pt 7, Ch 1, 1.1 General 1.1.11* and *Pt 7, Ch 1, 9 Riser systems*
Ice Class	Assigned where a unit is strengthened for specific ice conditions. Supplementary notations are provided.	*Pt 3, Ch 6 Units for Transit and Operation in Ice* *Pt 4, Ch 10, 1.3 Navigation in ice*

ISIS	Integrated Software Intensive System. Assigned when the integrated computer system controls a number of services.	*Pt 3, Ch 15 Integrated Software Intensive Systems*
with water spray	Assigned to a unit intended for fire-fighting operations and is fitted with a system which will provide an effective cooling spray of water.	*Pt 3, Ch 5 Fire-fighting Units*
LA	Mandatory lifting appliance(s). Assigned where the lifting appliance(s) is considered to be an essential feature.	*Pt 3, Ch 4, 1.2 Class notations 1.2.8* *Pt 3, Ch 11 Lifting Appliances and Support Arrangements* *Pt 3, Ch 16, 1.4 Class notations 1.4.6* *Code for Lifting Appliances in a Marine Environment, July 2016*
PC	Crane(s). Assigned where the unit's main deck crane(s) are included at the owner's request	*Pt 3, Ch 11 Lifting Appliances and Support Arrangements* *Code for Lifting Appliances in a Marine Environment, July 2016*
PL	Personnel lift(s). Assigned where personnel lift(s) are included at the owner's request	*Pt 3, Ch 11 Lifting Appliances and Support Arrangements* *Code for Lifting Appliances in a Marine Environment, July 2016*
PM	Positional mooring system. Assigned to mobile offshore units whose station-keeping complies with the Rules.	*Pt 1, Ch 3, 1.6 Planned survey programme 1.6.3,* *Pt 1, Ch 3, 4.2 Docking surveys 4.2.11* *Pt 1, Ch 3, 5.5 Positional mooring systems 5.5.5.* *Pt 3, Ch 10 Positional Mooring Systems*
PMC	Positional mooring system for mooring in close proximity to other vessels or units. Assigned to mobile offshore units whose station-keeping complies with the Rules.	*Pt 3, Ch 10 Positional Mooring Systems*
TA(1), TA(2), TA(3)	Assigned where the positional mooring system is assisted by thrusters. The number in brackets defines the thruster allowance.	*Pt 3, Ch 10 Positional Mooring Systems*

Appendix 2 Descriptions

Descriptive qualification notes may be agreed indicating the type of unit in greater detail than is contained in the class notation, and/or providing additional information about the design and construction.

Descriptive Notes:		
Description	**Information**	**Further information**
Semi-submersible		
Tanker conversion	Unit based on converted tanker	
Turret mooring	Turret mooring (internal/external)	
Spread mooring	Multi-point positional mooring	
Disconnectable unit	Unit can be disconnected from fixed mooring	
Helideck	Helicopter deck approval	
COW (LR)	Crude oil washing certified by LR	ShipRight Procedures

SBT (LR)	Segregated ballast tanks certified by LR.	ShipRight Procedures
E	Supporting calculations have been performed in accordance with hull structural finite element and fatigue analysis procedures of a recognised Classification Society	ShipRight Procedures
ES	Enhanced Scantlings	ShipRight Procedures
SEA (HSS-n)	Ship Event Analysis (Hull Surveillance Systems)	ShipRight Procedures
SERS	Ship Emergency Response Service	ShipRight Procedures
SCM	Screwshaft Condition Monitoring	ShipRight Procedures *Pt 1, Ch 3, 12.4 Screwshaft Condition Monitoring (SCM)*
MCM	Machinery Condition Monitoring	ShipRight Procedures
MCBM	Machinery Condition Based Maintenance	ShipRight Procedures
MPMS	Machinery Planned Maintenance Scheme	ShipRight Procedures
RCM	Reliability Centred Maintenance	ShipRight Procedures
BWMP	Ballast Water Management Plan	ShipRight Procedures
ThCM	Thruster Condition Monitoring	ShipRight Procedures
ESP	Enhanced Survey Programme	Where the owner elects to undertake hull Special Survey in accordance with the requirements of *Pt 1, Ch 3, 7 Special Survey - Oil tankers (including ore/oil ships and ore/bulk/oil ships) - Hull requirements* of the *Rules and Regulations for the Classification of Ships, July 2016*
DRILL	See also class notations	When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration.
PPF	See also class notations	When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration.
Deep draught caisson unit		
Concrete hull		

Verification in Accordance with National Regulations for Offshore Installations

■ *Section 1* Conditions for verification

1.1 General requirements

1.1.1 It is the responsibility of Owners, Operators or Duty Holders to comply with all aspects of National Legislation applicable to units and installations engaged in petroleum activities in controlled waters.

1.1.2 When LR is requested by an Owner, Operator or Duty Holder to carry out verification in accordance with the Regulations of the coastal state authority, verification approval will be carried out in accordance with this Chapter.

1.1.3 Verification will be carried out to the specific provisions of the coastal state Regulations, as agreed with the Owner, Operator or Duty Holder, and appropriate to the proposed descriptive note and the type of unit and its function.

1.1.4 For the assignment of a National Authority descriptive note as defined in *Pt 1, Ch 2, 2.9 Descriptive Notes/ Supplementary Character*, compliance with the coastal state Regulations will be considered in addition to the requirements of the Rules.

1.1.5 Verification will be based on LR’s interpretation of the coastal state Regulations as applicable to the type of unit and its function. Where appropriate, the coastal state Regulations will take precedence over the Classification Rules if considered more stringent.

1.1.6 The verification approval will cover only the standards of design, construction, materials, workmanship, equipment, machinery, systems and installed plant as prescribed by the Regulations. Those aspects concerning operations, personnel equipment and the overall safety philosophy will be the responsibility of the Owner, Operator and/or Duty Holder.

1.1.7 LR can also advise Owners, Operators and/or Duty Holders on safety aspects and carry out risk analyses on their behalf, in order to provide the documentation required in the internal control system as stipulated by the coastal state.

1.2 Existing units

1.2.1 In the case of an existing classed mobile unit or installation which has been built in accordance with the legislation of a coastal state, other than that now required, LR will carry out a comparison with the coastal state Regulations as applicable. Deviations from the required coastal state Regulations which do not achieve an equivalent safety standard will be listed.

1.2.2 When an existing unit is converted or modified, any new modifications, technical equipment or system are to comply with the required coastal state Regulations, as applicable.

1.3 Recognised Codes and Standards

1.3.1 When the coastal state Regulations do not refer to specific Codes or Standards or define specific acceptance criteria, verification approval will be carried out in accordance with the class Rules or, where appropriate, in accordance with internationally recognised Codes and Standards. See *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

1.3.2 The class Rules and/or recognised Codes and Standards may also be used for verification approvals when they are considered to provide an equivalent standard to the coastal state Regulations or when additional requirements are considered necessary to meet LR’s interpretation of the Regulations.

1.3.3 The mixing of different parts of Codes and Standards is to be avoided.

■ *Section 2*
Documentation

2.1 Certificates

2.1.1 When the requirements of the coastal state Regulations have been complied with to LR's satisfaction, certificates and a design appraisal declaration will be issued.

2.1.2 In general, if there are non-compliances with any parts of the coastal state Regulations, the non-compliance items will be required to be cleared to LR's satisfaction before the issue of Interim Certificates of Classification by the Surveyors. Any deviations from the coastal state Regulations will be listed in the design appraisal declaration.

2.1.3 In the case of an existing unit, the requirements of *Pt 1, Ch 4, 1.2 Existing units* are to be complied with.

2.1.4 If there are any serious non-compliances with the coastal state Regulations which could have an effect on the overall safety of the vessel or installation, the National Authority descriptive note may be withheld at the discretion of the Classification Committee.

■ *Section 3*
Descriptive note

3.1 General

3.1.1 After verification approval has been carried out in accordance with *Pt 1, Ch 4, 1.1 General requirements* to LR's satisfaction, a National Authority descriptive note will be assigned by the Classification Committee in accordance with *Pt 1, Ch 2, 2.9 Descriptive Notes/Supplementary Character*.

3.1.2 National Authority descriptive notes may be utilised by the Owner, Operator or Duty Holder as part of the documentation required in the internal control system as stipulated by the coastal state Regulations.

3.1.3 When a National Authority descriptive note has been assigned in accordance with *Pt 1, Ch 2, 2.9 Descriptive Notes/ Supplementary Character*, an additional entry will be made on the Class Direct website.

■ *Section 4*
Survey requirements

4.1 General

4.1.1 New units, vessels and installations are to be built under LR's Special Survey and, during service, periodic surveys are to be carried out in accordance with *Pt 1, Ch 3 Periodical Survey Regulations*.

4.1.2 When a National Authority descriptive note has been assigned in accordance with *Pt 1, Ch 2, 2.9 Descriptive Notes/ Supplementary Character*, the condition of the unit, vessel or installation shall be documented by periodic surveys in accordance with the applicable coastal state Regulations.

4.1.3 A routine system for planning and implementation of periodic surveys for condition monitoring of the unit, vessel or installation in accordance with the applicable coastal state Regulations shall be proposed by the Owner, Operator and/or Duty Holder and be agreed with LR.

4.1.4 In general, condition monitoring surveys as required by the coastal state Regulations should be carried out at the same time as normal periodical class surveys in accordance with *Pt 1, Ch 3 Periodical Survey Regulations*.

Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards

■ *Section 1* Application

1.1 General

1.1.1 Risk assessment techniques may be used to provide justification for the assignment of Class. Risk assessment techniques may be systematically applied to the whole of an installation or to individual systems, sub-systems or components.

1.1.2 Where risk assessment is applied to only part of an installation, the remainder of the installation is to be designed, constructed and maintained in accordance with the remaining Parts of these Rules.

1.1.3 Risk assessment provides a systematic method for the assessment of the risks posed to the safety and integrity of the installation or its parts.

1.1.4 Risk assessment may be used to define the basis of classification, by:

(a) identifying the hazards to safety and integrity of the installation, and evaluating them considering both consequence and frequency;
(b) identifying systems or elements of the installation that are critical in relation to the hazards; and
(c) defining performance standards which the critical systems or elements must meet to prevent, detect, control, mitigate or recover from, the identified hazards.

1.1.5 An installation, for which risk assessment has been applied in whole or in part, will be classed by Lloyd's Register (hereinafter referred to as 'LR'), provided LR has verified that all relevant critical elements are identified, are suitable for their intended purpose, and meet their required performance standards in design, construction, installation and function. Otherwise, classification will be subject to compliance with LR's Rules.

1.1.6 Similarly, an installation will continue to be classed by LR, provided LR has verified that all critical elements remain in good order and condition, and continue to meet their performance standards in operation. Otherwise, classification will be subject to continued compliance with LR's Rules.

1.1.7 It is the responsibility of the Owner/Operator to comply with any requirements of the National Administration. Where risk assessment results in the definition of performance standards different from those required by the National Administration or IMO Conventions, it is the responsibility of the Owner/Operator to obtain the necessary acceptance of the National Administration.

1.1.8 Classification using risk assessment relates to the performance standards of the identified critical elements for the safety and integrity of the installation. Operating procedures, including those developed in support of risk assessments for classification, are the responsibility of the Owner/Operator.

1.1.9 LR will implement a management scheme to control the process of applying risk assessment methodology to classification of an installation. Key stages subject to LR approval are detailed in this Chapter. The Owner/Operator is to accept and co-operate with the discipline of this management scheme.

1.1.10 LR will manage its own activities which are required to verify compliance with the agreed performance standards, by issuing project-specific work instructions to its design review and field personnel. The process will be documented to provide an audit record.

Section 2
Definitions

2.1 Hazard

2.1.1 A 'hazard' is a situation with potential to cause harm or damage to the installation in terms of its safety and integrity.

2.2 Critical element

2.2.1 A 'critical element' is a part of the installation, or a system, sub-system or component, which is essential to the safety and integrity of the installation in relation to the identified hazards.

2.2.2 Critical elements are identified on the basis that:

(a) their failure could cause or contribute substantially to a reduction in installation safety or loss of integrity; or
(b) their purpose is to prevent or limit the effect of hazards which threaten such integrity.

2.3 Risk

2.3.1 'Risk' is the likelihood that a specified undesired event will occur within a specified period of time, or in specified circumstances.

2.4 Risk assessment

2.4.1 'Risk assessment' is the evaluation of the likelihood of specified undesired consequences to the safety and integrity of the installation, together with the value judgements made concerning the significance of the results.

2.5 Risk acceptance criteria

2.5.1 'Risk acceptance criteria' are the criteria to be applied to the results of the risk assessment, to demonstrate that the installation is capable of providing an acceptable level of safety and integrity.

2.6 Performance standards

2.6.1 Performance standards are statements that can be expressed in qualitative or quantitative terms, of the performance required of a critical element in order that it will manage the identified hazards to ensure the safety and integrity of the installation. Management of hazards may be achieved by the prevention, detection, control, mitigation, or recovery from these hazards.

2.7 Verification

2.7.1 Within the Classification process, 'Verification' is the confirmation by a process of examination by LR of the design, manufacturing, construction, installation and commissioning of the critical elements in order to show that they meet the required performance standards.

2.7.2 For the continuation of Classification in-service, 'Verification' is the confirmation by a process of examination by LR, taking into account the Inspection and Maintenance Plan activities, that the identified critical elements remain in good order and condition, and continue to meet their required performance standards in operation.

2.8 Inspection and maintenance plan

2.8.1 The 'Inspection and Maintenance Plan' is the Owner/Operator's programme of scheduled inspection and maintenance activities that ensure the required performance standards continue to be met in service, to maintain the safety and integrity of the installation against the identified hazards.

Section 3
Methodology

3.1 General

3.1.1 Risk assessment requires the consideration of hazards and the likelihood of the hazards' consequences, and the means of hazard management.

3.1.2 The specific risk-based methodology used is to be in accordance with an applicable and recognised International or National Standard or Code.

3.1.3 The methodology is subject to approval by LR. The earliest engagement with class is encouraged when riskbased techniques are to be used as part of any design submission. This should happen far earlier than normal class approval, to ensure the approach adopted is acceptable, and does not result in project delay.

3.1.4 If risk assessment is used to examine individual systems, sub-systems, or components of an installation, a clear boundary marking the limit of such systems is to be identified.

3.1.5 These boundaries are subject to approval by LR.

3.2 Identification of hazards

3.2.1 Hazards that may threaten safety or integrity of the installation are to be identified.

3.2.2 Hazards to be considered are to include, but not be limited to, the following, as applicable:

- Blow out from wells.
- Hydrocarbon release, in particular, cryogenic jet, pool, drip or vapour.
- Fire and explosion incidents.
- Dropped objects.
- Ship and helicopter collision.
- Extreme weather and environment conditions.
- Loss of stability.
- Loss of structural integrity.
- Loss of systems essential to maintain the integrity of the installation.
- Loss of mooring system.

3.2.3 National Administration requirements may specify other hazards to be considered.

3.3 Ranking of hazards

3.3.1 The identified hazards are to be screened to provide a ranking of the hazards in terms of the consequences and likelihoods. Major hazards are those hazards that pose a significant threat to the safety and integrity of the installation.

3.3.2 The major hazards identified are subject to approval by LR.

3.3.3 Frequency analysis is an examination of the likelihood of the occurrence of hazardous events. The frequencies of occurrence of major hazards are to be estimated by suitable techniques, using appropriate occurrence or failure rate data. Both the likelihood of consequences and those consequences are to be analysed.

3.3.4 Consequence analysis is to consider the effects of hazardous events on the safety and integrity of the installation. Consequence analysis provides input to calculations of risk, and design information for risk reduction measures.

3.3.5 An assessment is to be performed to evaluate the availability of the emergency systems of the installation. Emergency systems are those systems that are required to operate when a hazard occurs, to protect the safety and integrity of the installation.

3.3.6 Emergency systems are to be assessed to evaluate their vulnerability to hazards that may occur.

3.4 Risk assessment

3.4.1 The risk is to be assessed for each of the possible failure modes identified. The risks from all the outcome events are to be considered together to assess the overall risk to the installation. This summation forms the baseline against which further risk reduction measures can be evaluated and a means of showing where the major risk contributors are in the installation.

3.4.2 The results of the risk assessment are subject to approval by LR.

3.5 Acceptance criteria

3.5.1 LR's Rules have been developed to the point where they achieve a standard of design and construction quality that ensures an acceptable level of safety and assurance of integrity of the installation. Provided that the Rules are followed throughout all the design and construction of the installation, this would ensure that the installation has an acceptable level of safety and assurance of integrity. Deviations from the Rules, using risk assessment as a method for justifying Class, must therefore demonstrate that such changes to the design and construction of an installation or its parts do not result in an unacceptable level of safety or integrity of the installation.

3.5.2 LR will require the Owner/Operator to develop risk acceptance criteria to be achieved by the design and maintained in service, to ensure the safety and integrity of the installation in line with the spirit and intent of LR's Rules.

3.5.3 Risk acceptance criteria are subject to approval by LR.

3.6 Identification of critical elements

3.6.1 Critical elements of the installation are to be identified in relation to the major hazards to safety and integrity of the installation. Critical elements provide the means to prevent, or to detect, control, mitigate and recover from, the hazards. Identification of critical elements is to be based on consequence of failure in relation to the reduction in safety and loss of integrity of the installation. Critical elements may be systems, sub-systems or components, of the installation.

3.6.2 Critical elements are subject to approval by LR.

3.7 Reducing the risks

3.7.1 For new construction, it is expected that the risk assessment will be initiated at the concept design stage. Opportunities may be identified for reducing the risks to the installation in its design. The aim is to achieve inherent safety by eliminating potential hazards. Where this is not practicable, a series of measures is to be applied which in order of preference prevent, detect, control, mitigate and allow recovery from the hazards.

3.8 Performance standards

3.8.1 Performance standards are to be developed for the critical elements in order that they will manage the identified hazards.

3.8.2 Performance standards are subject to approval by LR.

■ *Section 4*
Verification – New Construction

4.1 General

4.1.1 LR requires to verify that all critical elements have been identified, are suitable for their intended purpose, and that they meet their required performance standards to ensure the safety and integrity of the installation.

4.1.2 Verification is to be based on performance standards that are subject to approval by LR for each critical system/element derived from the risk assessment.

4.1.3 LR will produce a project-specific Verification Plan for each case. This will cover the following key aspects:

(a) Review and approval of critical elements.

(b) Review and approval of performance standards derived from the risk assessment.

(c) Examination of design to confirm that the critical elements meet the agreed performance standards.

(d) Examination during manufacture, construction, installation and commissioning to confirm that the critical elements meet the approved performance standards.

4.1.4 LR will apply a verification management process for new construction projects. This will include the projectspecific Verification Plan, and detailed work instructions for verification of each critical element at each stage of the project. The Owner/Operator is to co-operate with this management process and the requirements of the Verification Plan, and is to provide all necessary information and access for LR to carry out its verification tasks.

■ *Section 5* **Verification – In service**

5.1 General

5.1.1 To maintain Classification in service, LR requires to verify that all critical elements for the operational phase have been identified, are suitable for their intended purpose, and that they remain in good repair and efficient condition and that they continue meet their required performance standards.

5.1.2 Verification is to be based on performance standards which are subject to approval by LR for each critical system/element derived from the risk assessment.

5.1.3 LR will produce a project-specific in-service Verification Plan for each case. This will cover the following key aspects:

(a) Review and approval of critical elements.
(b) Review and approval of performance standards derived from risk assessment.
(c) Review and approval of the Owner/Operator's Inspection and Maintenance Plan.
(d) Monitoring the execution of the Owner/Operator's Inspection and Maintenance Plan.
(e) Examination of the installation and records at intervals and frequency commensurate with level of development of Owner/Operator's Inspection and Maintenance Plan.
(f) Examination of design, construction, installation and commissioning of any modifications.

5.1.4 LR will develop the Verification Plan for in-service activities to suit the Owner/Operator's methodology for inspection and maintenance. This will detail the examination work associated with each critical system/element.

5.1.5 LR's review of the Owner/Operator's Inspection and Maintenance Plan will include:

(a) Management objectives and structure.
(b) Management systems.
(c) Planning/scheduling/reporting.
(d) Data evaluation and determination of inspection intervals.
(e) Methods of inspection/testing/monitoring.
(f) Competency, resourcing and training of personnel used for inspection and testing.
(g) Procurement, calibration and maintenance of maintenance and test equipment.
(h) Software systems for inspection and maintenance planning and recording.
(i) Quality Assurance and Quality Control.

5.1.6 Following review of the Owner/Operator's Inspection and Maintenance Plan, LR will develop a Verification Plan with an appropriate level and depth of examination to confirm that the elements identified as critical in relation to class continue to meet the approved performance standards. LR verification activities may include review of records, audit of procedures and activities of inspectors acting for the Owner/Operator, sample checks and physical examination of the installation, as appropriate.

5.1.7 Any revision of the Owner/Operator's Inspection and Maintenance Plan for the critical elements is to be carried out in consultation with LR and is subject to approval by LR.

5.1.8 The Owner/Operator is to co-operate with the requirements of the Verification Plan, and is to provide all necessary information and access for LR to carry out its verification tasks.

5.1.9 Verification activities will take place on a continuous basis as determined in the Verification Plan. Verification status reports will be generated by LR at appropriate intervals (usually annual) to facilitate renewals of any National Administration statutory certificates and maintenance of class.

5.1.10 The Verification Plan will also include a system for reporting and recording of conditions of class that will indicate clearly the timescales for any remedial actions.

5.1.11 Based on the findings of the Verification activities, LR reserves the right to increase or decrease the level and frequency of activities.

5.1.12 Class may be suspended or withdrawn, if deemed necessary, at the discretion of the Classification Committee.

■ *Section 1* Definition

1.1 General

1.1.1 The Risk Based Inspection (hereinafter referred to as 'RBI) scheme is an alternative to the traditional periodical survey regime. It is applied by following an RBI Plan which has been approved by LR, with the purpose of detecting and monitoring system, sub-system, equipment and component degradation and applying appropriate decision criteria to manage risk to acceptable levels.

1.1.2 This chapter provides for the use of risk-based inspection techniques in the derivation of a suitable equivalent inspection regime. This should not be confused with the intent of the previous *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards* which is to establish arrangements enabling Classification of an asset using Risk Assessment Techniques to establish alternatives to prescriptive Rule requirements. Inspection regimes derived in accordance with the requirements of this chapter will normally satisfy those of *Pt 1, Ch 5, 5 Verification – In service* where this is applied.

■ *Section 2* Scope

2.1 General

2.1.1 The RBI scheme may be applied to floating offshore installations at a fixed location.

2.1.2 The RBI scheme may be applied to the following areas of a unit:

- Hull (including internal structures, tanks, underwater aspects, appendages and openings)
- Machinery
- Turret and Moorings
- Risers
- Process Systems

2.1.3 The RBI scheme may be applied to new constructions where the RBI Plan should be developed during the design process. RBI may be applied to existing facilities where the Owner/Operator can demonstrate there is sufficient technical knowledge and unit historical data to develop an RBI Plan to meet the purpose stated in *Pt 1, Ch 6, 1 Definition*.

■ *Section 3* Application

3.1 General

3.1.1 RBI techniques may be used to provide justification for the assignment of Class. RBI techniques may be systematically applied to the whole of an installation or to individual systems, sub-systems or components.

3.1.2 Where RBI is applied to only part of an installation, the remainder of the installation is to be designed, constructed and maintained in accordance with the remaining Parts of these Rules.

3.1.3 Similarly, a unit will continue to be classed by LR, provided LR has verified that all critical elements remain in good order and condition, and continue to meet their standards in operation. Otherwise, classification will be subject to continued compliance with LR's Rules.

3.1.4 It is the responsibility of the Owner/Operator to comply with any requirements of the National Administration. Where an RBI plan differs from those required by the National Administration or IMO Conventions, it is the responsibility of the Owner/Operator to obtain the necessary acceptance of the National Administration.

3.1.5 It is the responsibility of the Owner/Operator to develop, operate and review application of the RBI Plan and the RBI Plan is then to be approved by LR. The Owner/Operator shall demonstrate that the plan is being regularly reviewed according to the review schedule and any changes to the approved inspection regime are recorded in a satisfactory manner to enable audit and continued approval of the RBI Plan.

3.1.6 Lloyd's Register's Guidance Notes for the Risk Based Inspection of Offshore Units define acceptable RBI methodologies.

3.2 Survey using Risk Based Inspection

3.2.1 Where Classification using Risk Based Inspection techniques is proposed, surveys should meet the requirements laid out in *Pt 1, Ch 5, 4 Verification – New Construction*.

■ *Section 4*
Core Requirements

4.1 Preparation and Planning

4.1.1 The Owner/Operator is to submit the proposed RBI Plan containing details of the code/standard that they propose to apply to the unit to LR for approval. The RBI Plan shall demonstrate that the Owner/Operator has adequately considered:

- Compilation of sufficient qualitative and quantitative data to develop the RBI plan.
- Identification of critical elements
- Risk bands
- Mitigation measures
- Audit techniques
- Management structure.

4.2 Inspection and Surveys

4.2.1 The approved RBI Plan shall detail the survey regime for the specific unit in conjunction with the following surveys.

(a) Annual Survey: Annual Surveys are to be held on all units within three months, before or after each anniversary of the completion, commissioning or Special Survey. At Annual Survey, the Surveyor is to examine the unit and machinery, by nonintrusive survey, in order to be satisfied as to their general condition.

(b) Tanks will be credited on the basis of the approved and maintained RBI Plan which may include acceptance of tanks based on inspection of others which are agreed (with LR) as representative. The use of such "representative tanks" should be fully justified within the RBI plan:

- For tank entry, where intervals in excess of the usual Class periodic intervals are proposed the justifications with supporting reports are to be submitted for review by LR. This review will encompass, but not be limited to, coatings, environment, fatigue hot spots, design calculations and operational philosophy.
- Void spaces will be considered subject to corrosion mechanisms, unless suitably inerted and protected by a demonstrable control system. Where void spaces are demonstrability protected the RBI Plan may define a less intrusive approach. In instances where a void space undergoes a change of use the RBI Plan is to be reassessed for these spaces taking into account the change of use, this applies even where the change of use is temporary or a one off occurrence (For example a void space changing use to a sea water ballast space will then be considered a sea water ballast tank).

- For conventional oil-based hydrocarbon tanks where intervals in excess of the usual Class periodic interval are proposed the justifications backed up by the supporting reports are to be submitted for review by LR. This is to cover but not be limited to: coatings, environment, fatigue hot spots, chemical composition of hydrocarbons/cargo.
- For LNG/LPG tanks the manufacturer may propose the inspection interval for approval.

(c) Machinery The approved RBI Plan will demonstrate the rationale proposed for machinery inspections which may include reference to manufacturer recommendations.

(d) Offshore In Water Surveys (OIWS) In-Water surveys may be conducted by LR-Approved Service Providers and in the presence of an LR Surveyor. The Owner/Operator is to propose the In-Water inspection regime within the RBI Plan submitted to LR for approval.

(e) Special Survey: Special Survey will be credited five yearly on the basis of the approved RBI Plan being adhered to.

4.3 Review

4.3.1 Approval for the continued application of the RBI scheme will be determined by an Annual Audit of RBI documentation and survey reports by Lloyd's Register.

Contents

Section 1
Rules for the Manufacture Testing and Certification of Materials

1.1 Reference

Please see *Rules for the Manufacture, Testing and Certification of Materials, July 2016*

Contents

Contents

■ *Section 1* Rule Application

1.1 General

1.1.1 This Part is applicable to all types of offshore units as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*. Units of unconventional type or form will receive individual consideration based on the general standards of these Rules.

1.1.2 In addition to the Rule requirements for Classification, attention is to be given to the relevant statutory Regulations of the National Administrations in the area of operation and also the country of registration, as applicable, *see Pt 1, Ch 2, 1 Conditions for classification*.

1.1.3 The requirements stated in this Part for the particular unit types and special features class notations are supplementary to those stated in other Parts of these Rules.

■ *Section 2* Information required

2.1 General

2.1.1 General requirements regarding information required are given in *Pt 3, Ch 1, 5 Information required* of the Rules for Ships, which are to be complied with as applicable.

2.1.2 Additional plans, documents and data are to be submitted for approval and information as required by the relevant Parts of these Rules, together with the additional information related to the unit type and its specialised function as defined in this Part.

2.1.3 Where an **OIWS** class notation, for In-water Survey, is to be assigned, *see Pt 1, Ch 2 Classification Regulations*, plans and information covering the following items are to be submitted as applicable:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets is to be verified with the unit afloat.
- Details and arrangements for inspecting thrusters and sea chests.
- Details showing how stern bush clearances are to be inspected and measured with the unit afloat.
- Details of arrangements for servicing and unshipping thrusters.
- Details and arrangements for servicing sea inlet valves and checking sea chests.
- Details of underwater marking, *see Pt 3, Ch 1, 6 Underwater marking*.
- Details of coating systems and cathodic protection, *see Pt 8 CORROSION CONTROL*.

2.1.4 Approved plans and information covering the items detailed in *Pt 3, Ch 1, 2.1 General 2.1.3* are to be placed on board the unit.

2.2 Construction booklet

2.2.1 A construction booklet including a set of plans showing the exact location and extent of application of different grades and mechanical properties of structural materials, together with welding procedures employed for primary structure, is to be submitted for approval and a copy to be placed aboard the unit. Any other relevant construction information is to be included in the booklet, including restrictions or prohibitions regarding repairs or modifications.

2.2.2 Similar information is to be provided when aluminium alloy or other materials are used in the construction of the unit.

2.2.3 Copies of the main scantlings plans and details of the corrosion control system fitted are to be placed on board the unit.

2.3 Demarcation between Process and Marine Systems

2.3.1 A classification demarcation plan is to be submitted for approval that identifies any boundaries of classification.

2.3.2 The unit will encompass a split between the traditional Classification scope and that nominally described as process plant. It is noted that particularly with respect to new build projects the differentiation can lack clarity and it is not purely a function of location of the systems on the unit. Accordingly, a list of items to be considered under Classification requirements is to be developed, this may be extracted from the project equipment list, associated P&ID’s and shall be agreed with LR. The equipment list shall also be used to identify those systems which fall inside and outside of Class and will form the basis of a classification demarcation plan for the unit.

2.3.3 It should be noted that the location of an item rather than its function can influence the decision for inclusion within the Classification list of items. By example a tank serving a topsides process, that would normally be considered part of the topsides process plant, should be considered a Class item if it is located within the hull and adversely impacts the overall risk.

2.3.4 It should be noted that the forgoing has been written with facilities encompassing a significant process plant in mind. However, it is recognised that other facilities e.g. crane barges will also benefit from this approach. Accordingly, in these instances, an equipment list, associated P&ID’s, if appropriate, and plot plan are to be submitted for review.

■ *Section 3*
Operations manual

3.1 General

3.1.1 A manual of operating instructions is to be prepared and placed on board each unit and should be made readily available to all concerned in the safe operation of the unit, *see also Pt 3, Ch 1, 3.2 Information to be included 3.2.4*.

3.1.2 It is the responsibility of the Owner to provide in the Operations Manual all the necessary instructions and limits on the operation of the unit to ensure that the environmental and operating loading conditions on which the Classification is based will not be exceeded in service.

3.1.3 Where a National Administration has a specific requirement regarding the contents of the Operations Manual, it is the responsibility of the Owner to comply with such Regulations.

3.1.4 The Operations Manual is to be submitted when the plans of the unit are being approved by LR. The Operations Manual will be reviewed in respect of those aspects covered by Classification only.

3.1.5 Where a unit is modified during its service life, it is the Owner’s responsibility to update the Operations Manual, as necessary, and advise LR of any changes which may affect the Classification of the installation.

3.2 Information to be included

3.2.1 In general, the Operations Manual should include the following minimum information, as applicable:

- General description and particulars of the unit.
- Chain of command and general responsibilities during all normal operating modes and emergency operations.

- Limiting design data for each approved mode of operation, including design and variable loading, draughts, air gap, wave height, wave period, wind, current, minimum sea and air temperatures, assumed sea bed conditions, orientation, and any other applicable environmental factors, such as icing.
- A description of any inherent operational limitations for each mode of operation and for each change in mode of operation. For ship units and other surface type units, *see also Pt 3, Ch 1, 3.2 Information to be included 3.2.4*.
- Permissible deck loading plan.
- General arrangement plans showing watertight and weathertight boundaries.
- The location and type of watertight and weathertight closures, vents, air pipes, etc., and the location of downflooding points.
- The location, type and weights of permanent ballast installed on the unit.
- A description of the signals used in the general alarm, public address, fire and gas alarm systems.
- Hydrostatic curves, or equivalent data.
- A capacity plan showing the capacities and the centres of gravity of tanks and bulk material stowage spaces.
- Tank sounding tables or curves showing capacities, the centres of gravity in graduated intervals and the free surface data of each tank.
- Plans and description of the ballast system and instructions for ballasting.
- Plan indicating hazardous areas.
- Fire control and safety/evacuation plans.
- Lightship data based on the results of an inclining experiment, etc.
- Stability information in the form of maximum KG versus draught curve, or other suitable parameters, based upon compliance with the required intact and damaged stability criteria.
- Representative examples of loading conditions for each approved mode of operation, together with the means for evaluation of other loading conditions. For ship units and other surface type units, *see also Pt 3, Ch 1, 3.2 Information to be included 3.2.4*.
- Positional mooring system, and limiting conditions of operation.
- Description and limitations of any onboard computer used in operations such as ballasting, anchoring, dynamic positioning and in trim and stability calculations.
- Plan of towing arrangements and limiting conditions of operation.
- Description of the main power system and limiting conditions of operation.
- Details of emergency shut-down procedures.
- Identification of the helicopter used for the design of the helicopter deck.

3.2.2 Instructions for the operation of the unit are to include precautions to be taken in adverse weather, changing mode of operation, any inherent limitations of operations, approximate time required for meeting severe storm conditions, mooring pattern/heading.

3.2.3 For self-elevating units, the manual is to include instructions on safety during jacking-up and jacking-down of the hull, over the period of time that the unit is in the elevated position, and during extreme weather conditions while in transit, including the positioning and securing of legs, cantilever drill floor structures and heavy cargo and equipment which might shift position. Limitations on the maximum permissible rigid body motions of the unit, and allowable sea states whilst elevating or lowering the legs.

3.2.4 For ship units and other surface type units, sufficient information is to be supplied to the Master/Operator to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the unit's structure. This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument, *see Pt 1, Ch 2, 1 Conditions for classification*. The Loading Manual may form part of the Operations Manual, or may be a separate document.

■ *Section 4*
Materials

4.1 General

4.1.1 The Rules relate in general to the construction of steel units of welded construction, although consideration will be given to the use of other materials. For concrete structures, *see Pt 9 CONCRETE UNIT STRUCTURES*.

4.1.2 The materials used for the construction and repair of units and installed machinery are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

4.1.3 As an alternative, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

4.1.4 Materials for specialised areas of the unit, related to its function or special features class notation, are to be in accordance with the relevant Chapters of this Part, *see also Pt 3, Ch 1, 4.3 Structural categories*.

4.2 Material selection

4.2.1 Materials are to be selected in accordance with the requirements of the design in respect of static strength, fatigue strength, fracture resistance and corrosion resistance, as appropriate.

4.2.2 The grades of steel to be used in the construction of the unit are to be related to the thickness of the material, the location on the unit and the minimum design temperature, *see Pt 3, Ch 1, 4.4 Minimum design temperature*.

4.2.3 The grades of steel to be used for the drilling plant and the production and process plant are to be in accordance with the requirements of *Pt 3, Ch 7 Drilling Plant Facility* and *Pt 3, Ch 8 Process Plant Facility* respectively.

4.2.4 The effects of corrosion, either from the environment or from the products handled on the unit or its associated plant and machinery, are to be taken into account in the design.

4.3 Structural categories

4.3.1 The structural categories for the hull construction and the corresponding grades of steel used in the structure are to be in accordance with *Pt 4, Ch 2 Materials*

4.3.2 The structural categories for supporting structures for drilling plant and production and process plant are to be in accordance with *Pt 3, Ch 7 Drilling Plant Facility* and *Pt 3, Ch 8 Process Plant Facility* respectively.

4.4 Minimum design temperature

4.4.1 The minimum design temperature is a reference temperature used as a criterion for the selection of the grade of steel to be used.

4.4.2 The minimum design air and sea temperatures for exposed structure are to be taken as the lowest daily average temperature for the unit's proposed area of operation, based on a return period of occurrence of:

(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a fixed location.

Where

Daily average temperature = the average temperature during one day and night.

The temperature is to be rounded down to the nearest degree Celsius. Consideration is to be given to the minimum temperature at the ship yard during construction and testing, and along transit routes for any voyage of the unit from one geographical location to another.

4.4.3 The minimum design temperature (MDT) for drilling plant and production and process plant is to be defined by the designers/Builders, but when appropriate the MDT should not be higher than the MDT for the exposed structure defined in *Pt 3, Ch 1, 4.4 Minimum design temperature 4.4.2*.

4.5 Aluminium structure, fittings and paint

4.5.1 The use of aluminium alloy is permitted for secondary structure, as defined in *Pt 4, Ch 2 Materials*

4.5.2 Where aluminium alloy is used for secondary structure, the material is to conform with the requirements of *Ch 8 Aluminium Alloys* of the Rules for Materials.

4.5.3 The use of aluminium alloy for primary structure will be specially considered.

4.5.4 Where aluminium alloy is used in the construction of fire divisions, it is to be suitably insulated in accordance with the requirements of the appropriate National Administration, *see Pt 3, Ch 1, 1.1 General 1.1.2*

4.5.5 Since aluminium alloys may, under certain circumstances, give rise to incendive sparking on impact with steel, the following requirements are to be complied with:

(a) Aluminium fittings in tanks used for the storage of oil, and in cofferdams and pump-rooms in oil storage units are to be avoided wherever possible.
(b) Where fitted, aluminium fittings, anodes and supports in tanks used for the storage of oil, cofferdams and pump-rooms are to satisfy the requirements specified in *Pt 8, Ch 2, 5 Cathodic protection in tanks* for aluminium anodes.
(c) The danger of mistaking aluminium anodes for zinc anodes must be emphasised. This gives rise to increased hazard if aluminium anodes are inadvertently fitted in unsuitable locations.
(d) The undersides of heavy portable aluminium structures such as gangways, etc., are to be protected by means of hard plastic or wood covers, in order to avoid the creation of smears when dragged or rubbed across steel, which if subsequently struck, may create an incendive spark. It is recommended that such protection be permanently and securely attached to the structures.
(e) Aluminium is not to be used in hazardous areas on drilling units and production and oil storage units unless adequately protected, and full details submitted for approval. Aluminium is not to be used for hatch covers to any openings to oil storage tanks.

4.5.6 For permissible locations of aluminium anodes, *see Pt 8, Ch 2, 5 Cathodic protection in tanks*.

4.5.7 The use of aluminium paint is to comply with the requirements of *Pt 8, Ch 3, 1 General requirements*.

■ *Section 5*
Corrosion control

5.1 General

5.1.1 The corrosion control of steelwork on all units is to be in accordance with *Pt 8 CORROSION CONTROL*. The corrosion protection of mooring systems is to comply with *Pt 3, Ch 10 Positional Mooring Systems*.

5.1.2 The basic Rule scantlings of the external submerged steel structure of units which are derived from *Pt 4, Ch 6 Local Strength* assume that appropriate coatings and an external cathodic protection system will be fitted. If the corrosion protection system of the submerged structure is not in accordance with the Rules the scantlings are to be suitably increased.

5.1.3 Ship units and other surface type units which are assigned an **OIWS** notation are to be fitted with external cathodic protection and external coating systems in accordance with *Pt 8 CORROSION CONTROL*.

■ *Section 6*
Underwater marking

6.1 General

6.1.1 Where an **OIWS** notation, for In-water Survey, is to be assigned, *see Pt 1, Ch 2 Classification Regulations*, the requirements of this Section are to be complied with.

6.1.2 The underwater structure of a unit intended to be surveyed on an In-water basis should have its main frames, bulkheads and joints, etc., clearly identified by suitable marking. Details are to be submitted for approval.

6.1.3 Marking should consist of raised lines, numerals and letters. In general, marking by welding is not to be used on ship units and other surface type units.

6.1.4 If marking is to be carried out by welding, the welds should be made with continuous runs and the quality of the workmanship should be to an equivalent standard as the main hull structure. Substantial runs should be laid, continuously, using large diameter electrodes and avoiding light runs as these are more likely to promote cracking. Sharp corners in the letters are to be avoided. Marking by welding is not permitted in highly stressed areas or over existing butts or seams. The welding procedures and consumables are to be submitted for approval.

6.1.5 On steel of Grade D or E or on higher tensile steel, low hydrogen electrodes should be used of a grade suitable for the steel. In the case of higher tensile steel, *see Ch 3, 3 Higher strength steels for ship and other structural applications* of the Rules for Materials, pre-heating to about 100°C should be adopted.

6.2 Design features

6.2.1 The following features are to be incorporated into the unit's design, where applicable, in order to facilitate the underwater inspection. When verified, they will be noted in the unit's classification for reference at subsequent surveys.

6.2.2 **Stern bearing**. For self-propelled units, means are to be provided for ascertaining that the seal assembly on oil-lubricated bearings is intact and for verifying that the clearance or weardown of the stern bearing is not excessive. For oil-lubricated bearings, this may only require accurate oil loss rate records and a check of the oil for contamination by sea-water or white metal. For wood or rubber bearings, an opening in the top of the rope guard and a suitable gauge or wedge would be sufficient for checking the clearance by a diver. For oil-lubricated metal stern bearings, weardown may be checked by external measurements between an exposed part of the seal unit and the stern tube bossing, or by use of the unit's weardown gauge, where the gauge wells are located outboard of the seals, or the unit can be tipped. For use of the weardown gauges, up-to-date records of the base depths are to be maintained on board. Whenever the stainless steel seal sleeve is renewed or machined, the base readings for the weardown gauge are to be re-established and noted in the unit's records and in the survey report.

6.2.3 **Rudder bearings**. For self-propelled units with rudders, means and access are to be provided for determining the condition and clearance of the rudder bearings, and for verifying that all parts of the pintle and gudgeon assemblies are intact and secure. This may require bolted access plates and a measuring arrangement.

6.2.4 **Sea suctions**. Means are to be provided to enable the diver to confirm that the sea suction openings are clear. Hinged sea suction grids would facilitate this operation.

6.2.5 **Sea valves**. For the Dry-docking Survey (Underwater Inspection) associated with the Special Survey, means must be provided to examine any sea valve.

6.2.6 Alternative arrangements to facilitate In-water Surveys will be considered; details are to be submitted to LR for approval.

■ *Section 7*
Permanent means of access

7.1 General

7.1.1 Each space within the unit should be provided with at least one permanent means of access to enable, throughout the life of a unit, overall and close-up inspections and thickness measurements of the unit's structures to be carried out by LR, the company, and the unit's personnel and others, as necessary. Such means of access should comply with the provisions of *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)*, paragraph 2.2 and with the Technical provisions for means of access for inspections, adopted by the Maritime Safety Committee by Resolution *Resolution MSC.133(76) - Adoption of Technical Provisions for Means of Access for Inspections - (adopted on 12 December 2002)*, as may be amended by the IMO.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to all drilling units engaged in drilling operations for the exploration and exploitation of petroleum, gas or other resources beneath the sea bed.

1.1.2 Surface type units are to comply with this Chapter, but reference should also be made to *Pt 4, Ch 4, 4 Surface type units*.

1.1.3 Units engaged in rock drilling or other similar work operations not related to petroleum or gas resources will be specially considered but should comply with the general requirements of this Chapter as applicable to the unit.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

Mobile offshore drilling unit; or
Drill ship.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Drilling units with an installed drilling plant facility which comply with the requirements of *Pt 3, Ch 7 Drilling Plant Facility* will be eligible for the assignment of the special features class notation **DRILL**.

1.2.4 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.2.5 When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration, a descriptive note will be included in the Class Direct website.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Structural arrangements of the unit related to drilling operations.
- Supporting structures for drilling equipment, bulk storage and raw water towers.
- Drill floor and derrick substructure.
- Drilling cantilevers.
- Structural arrangements in way of drilling wells.
- Structural mud tanks or pits.
- Deckhouses and modules related to drilling operations.
- Pipe racks and supports.
- Hazardous areas and ventilation.
- Pollution prevention.

1.4 Installation layout and safety

1.4.1 In principle, drilling units are to be divided into main functional areas to ensure that the following areas are separated and protected from each other:

(a) Drilling area:

Drill floor area

Mud circulation and treatment area.

(b) Auxiliary equipment area.

(c) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administration in the country of registration and the areas of operation as applicable, *see Pt 1, Ch 2, 1 Conditions for classification* and *Pt 7, Ch 3 Fire Safety*.

1.4.3 Additional requirements for safety systems and hazardous areas are given in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from the drilling area.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information, as required by *Pt 3, Ch 1, 2 Information required* and *Pt 4, Ch 1 General*, the following additional plans and information are to be submitted:

- General arrangement plans.
- General arrangement plans of drilling derrick and equipment.
- Structural plans of drill floor, drilling derrick supports, substructure, drilling equipment supports, pipe rack and supports.
- Structural arrangements in way of drilling wells.
- Movable drilling cantilevers and skid beams.
- Hull supporting structures.
- Hull structural plans of mud compartments, mud tanks and pump-rooms.
- Deckhouses and modules.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of*Pt 4 STEEL UNIT STRUCTURES* taking into account the drilling structures and applied equipment weights and forces introduced by the drilling operations. Attention should be paid to loads resulting from hull flexural effects at support points. For surface type units, *see* also *Pt 3, Ch 1, 1 Rule Application*.

2.2.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designers/Builders and calculations are to be submitted.

2.2.3 Strength calculations are to be submitted for moveable drilling cantilevers, skid beams and their supports. The clearances between the cantilever support claw and the skidding guides is the responsibility of the designers/Builders.

2.2.4 The maximum reaction forces from the drilling derrick are to be determined from an acceptable National Code or Standard and should take into account the load effects from vessel motions, the drillpipe setback, hook load, rotary table and tensioning equipment, *see Pt 3, Ch 7 Drilling Plant Facility*.

2.2.5 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick and other structures, the effects of ice loading is to be included in the calculations, *see Pt 4, Ch 3, 4 Structural design loads*.

2.2.6 The local structure should be reinforced for the component forces from drilling equipment and tensioner forces, and the design loadings are to be determined in accordance with *Pt 3, Ch 7 Drilling Plant Facility*.

2.2.7 The supporting structure and attachments under large equipment items are also to be designed for the emergency condition as defined in *Pt 3, Ch 8, 1.4 Plant design characteristics*

2.2.8 Attention should be paid to the capability of support structures to withstand buckling, *see Pt 4, Ch 5, 4 Buckling strength of primary members*.

2.2.9 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with*Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

2.3 Well structure

2.3.1 The primary hull strength of the unit is to be maintained in way of drilling wells and other large deck openings and suitable compensation is to be fitted as necessary. For surface type units the minimum hull modulus in way of the drilling well is to satisfy the Rule requirements for longitudinal strength.

2.3.2 Arrangements are to be made to ensure continuity of strength at the ends of longitudinal and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.3.3 The boundary bulkheads of drilling wells are to be designed for the maximum forces imposed by the drilling operations. The minimum scantlings of well bulkheads are to comply with the requirements for tank bulkheads in *Pt 4, Ch 6, 7 Bulkheads* using the load head measured to the top of the well, but in no case is the well plating to have a thickness less than 9,0 mm.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with *Pt 4, Ch 5, 2 Permissible stresses* but the minimum scantlings of the local structure are to comply with *Pt 4, Ch 6 Local Strength*. For surface type units, *see also Pt 4, Ch 4, 4 Surface type units*.

2.4.2 Permissible stresses for lattice type structures may be determined from an acceptable code, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.5 Mud tanks

2.5.1 The scantlings of structural mud tanks are not to be less than those required for tanks in *Pt 4, Ch 6, 7 Bulkheads* using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless otherwise agreed with LR.

2.5.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in *Pt 4, Ch 6, 7 Bulkheads*

2.6 Deckhouses and modules

2.6.1 The scantlings of structural deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*. Where deckhouses support equipment loads they are to be suitably reinforced.

2.6.2 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.6.3 When containerised modules can be subjected to wave loading the scantlings are not to be less than required by 2.6.1.

2.7 Pipe racks

2.7.1 The pipe rack is to be designed for the following normal operating loads as applicable:

- Gravity loads.
- Maximum dynamic loads due to wave-induced unit motions.
- Direct wind loads.

- Ice and snow loads.

2.7.2 The pipe rack supports are also to be designed for an emergency condition as defined in *Pt 3, Ch 8, 1 General*.

2.7.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with *Pt 4, Ch 6, 4 Decks*

2.7.4 In the emergency condition arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.8 Bulk storage vessels

2.8.1 Free standing bulk storage vessels are to comply with the requirements of *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*

2.8.2 The deck supports under free standing bulk storage vessels are to comply with the requirements for local structure in *Pt 4, Ch 6 Local Strength*, taking into account the maximum design reaction forces.

2.8.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the code stress in accordance with *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

2.9 Watertight and weathertight integrity

2.9.1 The general requirements for watertight and weathertight integrity are to be in accordance with *Pt 4, Ch 7*.

2.9.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.9.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.9.4 Where free-standing bulk storage vessels penetrate watertight decks or flats the arrangements to ensure watertight integrity will be specially considered, *see Pt 3, Ch 2, 2.8 Bulk storage vessels 2.8.3*.

■ *Section 3* Hazardous areas and ventilation

3.1 Hazardous areas and ventilation

3.1.1 For the application of hazardous area classification and ventilation requirements for drilling units, *see Pt 7, Ch 2 Hazardous Areas and Ventilation*.

3.1.2 Ventilation in the vicinity of the mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.3 For units using oil-based mud, the tanks are to be provided with special ventilating arrangements, and for open systems the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4* Pollution prevention

4.1 General

4.1.1 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil or oily residues into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.2 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.3 Pollution prevention arrangements should be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the area of operation, as applicable.

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter apply to units engaged in production and/or crude oil or liquefied gas bulk storage and offloading at offshore locations. Production units have specialised structures and plant installed on board for production and/or processing crude oil or gas.

In general, oil storage units have integral tanks for the storage of crude oil in bulk and the Rules are primarily intended for units which are to store flammable liquids having a flash point not exceeding 60°C (closed-cup test).

Ship units with bulk storage tanks for liquefied gases or liquid chemicals are to comply with *Pt 3, Ch 3, 1.1 Application 1.1.4* and *Pt 3, Ch 3, 1.1 Application 1.1.5* respectively. Other unit types with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered on the basis of *Pt 3, Ch 3, 1.1 Application 1.1.4* and *Pt 3, Ch 3, 1.1 Application 1.1.5* as applicable.

1.1.2 Column-stabilised and self-elevating units which are intended to operate only at a fixed offshore location are to comply with this Chapter, but reference should be made to *Pt 3, Ch 1, 1 Rule Application*.

1.1.3 Ship units are to comply with this Chapter, in addition to *Pt 10 SHIP UNITS*.

1.1.4 Ship units required for the storage of liquefied gases in bulk are to comply with *Pt 11 PRODUCTION, STORAGE AND OFFLOADING OF LIQUEFIED GASES IN BULK*, in addition to *Pt 3, Ch 3, 1.1 Application 1.1.3*.

1.1.5 Ship units required for the storage of liquid chemicals in bulk are to comply with *Pt 3, Ch 3, 1.1 Application 1.1.3*, and in general with the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code), as interpreted by LR.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

- Floating production unit.
- Floating production and storage and offloading unit.
- Floating storage offloading unit.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Type class notations for units with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered by the Classification Committee.

1.2.4 When a unit is to be verified in accordance with Regulations of a Coastal State Authority/National Administration, an additional class notation may be assigned in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.2.5 Production units with an installed process plant facility, which comply with the requirements of *Pt 3, Ch 8 Process Plant Facility*, will be eligible for the assignment of the special features class notation **PPF**. For units with riser systems, *see also Pt 3, Ch 12 Riser Systems*.

1.2.6 When a **PPF** notation is not assigned to a unit with a process plant facility, classification of the unit will be subject to the process plant being certified by LR, or by another acceptable organisation.

1.2.7 Production units without an installed process plant facility are to comply with the general requirements of *Pt 3, Ch 8 Process Plant Facility* as applicable.

1.2.8 Units with an installed drilling plant facility, which comply with the requirements of *Pt 3, Ch 7 Drilling Plant Facility*, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.9 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- General arrangement.
- Structural arrangement of the unit.
- Supporting structures below production and process plant equipment, flare structures, and marine risers.
- Deckhouses and modules related to production operations.
- Loading of hot oils.
- Structural arrangement of oil storage tanks, cofferdams and pump-rooms.
- Access arrangements.
- Compartment minimum thickness.
- Hazardous areas and ventilation.
- Pollution prevention.

1.3.2 Where the unit is fitted with drilling equipment, the requirements of *Pt 3, Ch 2 Drilling Units* are to be complied with.

1.4 Installation layout and safety

1.4.1 In principle, production units are to be divided into main functional areas to ensure that the following areas as applicable are separated and protected from each other:

(a) Production area:

- Wellhead area.
- Processing area.

(b) Drilling area:

- Drill floor area.
- Mud circulation and treatment area.

(c) Auxiliary equipment area.

(d) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administrations in the country of registration and/or in the area of operation as applicable, *see Pt 1, Ch 2, 1 Conditions for classification* and *Pt 7, Ch 3 Fire Safety*.

1.4.3 Additional requirements for safety systems and hazardous areas are given in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from production and wellhead areas.

1.4.5 In general, production units with crude oil bulk storage tanks are to be designed so that the arrangement and separation of living quarters, storage tanks, machinery rooms, etc., are arranged in accordance with the *SOLAS - International Convention for the Safety of Life at Sea* as amended, Regulations 11-2/56. Where this is not practicable owing to the unconventional design construction of the unit, special consideration will be given to other arrangements which provide equivalent separation and protection. *See also Pt 1, Ch 2, 1.1 Application*. For ship units and surface type units with crude oil bulk storage tanks, the general arrangement and separation of spaces are to comply with *Pt 4, Ch 9 Double Hull Oil Tankers* of the Rules for Ships, or equivalent arrangements provided.

1.4.6 The position of the process plant in relation to storage tanks for crude oil, gas or other products will be specially considered, and consideration will be given to the requirements with regard to the provision of effective separation, methods of storage, loading and discharging arrangements.

1.4.7 Provision is to be made for purging, gas freeing, inerting or otherwise rendering safe crude oil bulk storage tanks, process plant and process storage facilities before the unit moves to a new location.

■ *Section 2* **Structure**

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by *Pt 3, Ch 1, 2 Information required* and *Pt 4, Ch 1 General* the following additional plans and information are to be submitted:

- General arrangement.
- General arrangement plans of the production plant and process equipment layout.
- Structural supports below plant equipment.
- Structural plans of crude oil tanks, ballast tanks, cofferdams, void spaces, pump-rooms and machinery spaces.
- Deckhouses and modules.

2.1.2 When the unit is fitted with drilling equipment, the additional plans required by *Pt 3, Ch 2, 2 Structure* are to be submitted as applicable.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of *Pt 4 STEEL UNIT STRUCTURES*, taking into account the type of unit, the imposed equipment weights and forces from the production and process plant, mooring forces and drilling plant, when fitted. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The supporting structure below equipment is to be designed for all operating conditions and the maximum design loadings from the production and process plant imposed on the structure are to be determined in accordance with *Pt 3, Ch 8 Process Plant Facility*.

2.2.3 Decks and other under-deck structure supporting the plant are to be suitable for the local loads at plant support points and an agreed uniformly distributed load acting on the deck, *see Pt 4, Ch 6, 2 Design heads*. The structure in way of marine risers is to be suitably reinforced for the imposed loads.

2.2.4 In general, all seatings, platform decks, girders and pillars supporting plant items are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads. Attention should be paid to the capability of support structures to withstand buckling, *see Pt 4, Ch 5, 4 Buckling strength of primary members*.

2.2.5 The strength of the unit in way of openings is to be maintained. Structure in way of openings of unusual size, configuration and/or shape may require investigation by structural analysis when requested by LR.

2.2.6 Insert plates of adequate thickness and steel grade, appropriate to the stress concentrations and locations, may be required in way of openings and structural discontinuities in primary structure.

2.2.7 Critical joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Where unavoidable, plate material with suitable through thickness properties will be required, *see Ch 3, 8 Plates with specified through thickness properties* of the Rules for Materials and *Pt 4, Ch 2, 4.1 General 4.1.3*.

2.2.8 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

2.2.9 Turret structures, swivel stacks, mooring arms and yoke structures, etc., are to comply with the requirements of *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures*.

2.3 Drilling structures

2.3.1 When a unit is fitted with a drilling derrick, the requirements of *Pt 3, Ch 2, 2 Structure* are to be complied with, as applicable.

2.3.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designer/Builders and calculations are to be submitted.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with *Pt 4, Ch 5, 2 Permissible stresses* but the minimum scantlings of the local structure are to comply with *Pt 4, Ch 6 Local Strength*. For ship units, *see Pt 10 SHIP UNITS*. For other surface type units, *see Pt 4, Ch 4 Structural Unit Types*.

2.4.2 Permissible stresses for lattice type structures may be determined for an acceptable Code, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*

2.5 Well structure

2.5.1 The primary hull strength of the unit is to be maintained in way of moonpools, turret openings, drilling wells and other large deck openings and suitable compensation is to be fitted, as necessary. For ship units and other surface type units, the continuity of longitudinal material is to be maintained, as far as is practicable, in way of turret openings and wells and the minimum hull modulus is to satisfy the Rule requirements for longitudinal strength.

2.5.2 Arrangements are to be made to ensure continuity of strength at the ends of moonpools and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.5.3 Circumturret bulkheads and the boundary bulkheads of moonpools and drilling wells are to be designed for the maximum forces imposed on the structure. For ship units, *see Pt 10 SHIP UNITS*. For other surface type units, *see Pt 4, Ch 4, 4 Surface type units*. For other unit types, *see Pt 4, Ch 6 Local Strength* .

2.6 Mud tanks

2.6.1 The scantlings of structural mud tanks are not to be less than those required for tanks in *Pt 4, Ch 6, 7 Bulkheads* using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless agreed otherwise with LR.

2.6.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in *Pt 4, Ch 6, 7 Bulkheads*.

2.7 Deckhouses and modules

2.7.1 The scantlings of structural deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*. Where deckhouses support equipment loads, they are to be suitably reinforced.

2.7.2 The strength of containerised modules, which do not form part of the main hull structure, will be specially considered in association with the design loadings.

2.7.3 When containerised modules can be subjected to wave loading, the scantlings are not to be less than required by *Pt 3, Ch 3, 2.7 Deckhouses and modules 2.7.1*.

2.8 Pipe racks

2.8.1 The pipe rack is to be designed for the following normal operating loads as applicable:

- Gravity loads.
- Maximum dynamic loads due to wave induced unit motions.
- Direct wind loads.
- Ice and snow loads.
- Hull flexure due to hull girder bending

2.8.2 The pipe rack supports are also to be designed for an emergency condition, as defined in *Pt 3, Ch 8, 1 General*.

2.8.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable, additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with *Pt 4, Ch 6, 4 Decks*.

2.8.4 In the emergency condition, arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.9 Bulk storage vessels

2.9.1 Free-standing bulk storage vessels are to comply with the requirements of *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

2.9.2 The deck supports under free-standing bulk storage vessels are to comply with the requirements for local structure in *Pt 4, Ch 6 Local Strength* taking into account the maximum design reaction forces.

2.9.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the Code stress in accordance with *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

2.10 Watertight and weathertight integrity

2.10.1 The general requirements for watertight and weathertight integrity are to be in accordance with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

2.10.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.10.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval. Free flooding pipes, which penetrate shell boundaries, are to have a wall thickness not less than the adjacent shell plating.

2.10.4 Where bulk storage vessels penetrate watertight decks or flats, the arrangements to ensure watertight integrity will be specially considered, *see Pt 3, Ch 3, 2.9 Bulk storage vessels 2.9.3*.

2.11 Access arrangements and closing appliances

2.11.1 For requirements in respect of coamings and closing of deck openings, *see Pt 4, Ch 7, 6 Miscellaneous openings*.

2.11.2 The access arrangements on ship units and other surface type units are to comply with *Pt 3, Ch 3, 2.12 Access to spaces in oil storage areas*. For other unit types, the general requirements of *Pt 3, Ch 3, 2.12 Access to spaces in oil storage areas* are to be complied with, as applicable.

2.11.3 Ladders and platforms in tanks, pump-rooms, cofferdams, access trunks and void spaces are to be securely fastened to the structure.

2.12 Access to spaces in oil storage areas

2.12.1 Access arrangements to tanks for the storage of oil in bulk and adjacent spaces, including cofferdams, voids, vertical wing and double bottom ballast tanks, is to be direct from the open deck and such as to ensure their complete inspection.

2.12.2 In column-stabilised units where access from the open deck is not practicable, access to oil storage tanks and adjacent spaces is to be from trunks which are mechanically ventilated in accordance with *Pt 3, Ch 3, 3 Hazardous areas and ventilation*. Every space is to be provided with a separate access without passing through adjacent spaces.

2.12.3 Access to double bottom tanks in way of oil storage tanks, where wing ballast tanks are omitted, is to be provided by trunks from the exposed deck led down the bulkhead. Alternative proposals will, however, be considered, provided the integrity of the inner bottom is maintained.

2.12.4 Access to double bottom spaces may also be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

2.12.5 Where a duct keel or pipe tunnel is fitted, and access is normally required for operational purposes, access is to be provided at each end and at least one other location at approximately mid-length. Access is to be directly from the exposed deck. Where an after access is to be provided from the pump-room to the duct keel, the access manhole from the pump-room to the duct keel is to be provided with an oiltight cover plate. Mechanical ventilation is to be provided and such spaces are to be

adequately ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for an adequate period. In addition, the atmosphere in the tunnel is to be sampled by a reliable gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

2.12.6 Every double bottom space is to be provided with separate access without passing through other neighbouring double bottom spaces.

2.12.7 Where the tanks are of confined or cellular construction, two separate means of access from the weather deck are to be provided, one to be provided at either end of the tank space.

2.12.8 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm x 600 mm.

2.12.9 Where practicable, at least one horizontal access opening of 600 mm x 800 mm clear opening is to be fitted in each horizontal girder in all spaces and weather deck to assist in rescue operations.

2.12.10 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating, unless gratings or other footholds are provided.

2.12.11 In double hull construction where the wing ballast tanks have restricted access through the vertical transverse webs, permanent arrangements are to be provided within the space to permit access for inspection at all heights in each bay. These arrangements, which should comprise fixed platforms, or other means, are to provide sufficiently close access to carry out Close-Up Surveys, as defined in *Pt 1, Ch 3 Periodical Survey Regulations*, using limited portable equipment where appropriate. Details of these arrangements are to be submitted for approval.

2.12.12 On units with very large oil storage tanks, it is recommended that consideration be given to providing permanent facilities for staging the interior of tanks situated within the oil storage region and of large tanks elsewhere. Suitable provisions would be:

- Staging which can be carried on board and utilised in any tank, including power-operated lift or platform systems.
- Enlargement of structural members to form permanent, safe platforms, e.g., bulkhead longitudinals widened to form stringers (in association with manholes through primary members).
- Provision of inspection/rest platforms at intervals down the length of access ladders.
- Provision of manholes in upper deck for access to staging in cargo tanks.

2.13 Access hatchways to oil storage tanks

2.13.1 The general requirements of *Pt 4, Ch 7, 6 Miscellaneous openings* are to be complied with.

2.14 Loading of hot oil in storage tanks

2.14.1 Hot oil may be loaded in oil storage tanks at the temperatures given below, without the need for temperature distribution and thermal stress calculations, provided the following temperatures are not exceeded during operations:

(a) 65°C for sea temperatures of 0°C and below;
(b) 75°C for sea temperatures of 5°C and above; and
(c) by linear interpolation between (a) and (b) above, for sea temperatures between 0°C and 5°C.

2.14.2 Where the stored oil is to be loaded or heated to higher temperatures than those specified in *Pt 3, Ch 3, 2.14 Loading of hot oil in storage tanks 2.14.1* before unloading, temperature distribution investigations and thermal stress calculations may be required. For ship units and other surface type units, *see Pt 4, Ch 9, 12 Cargo temperatures* of the Rules for Ships.

2.15 Compartment minimum thickness

2.15.1 On semi-submersible units, within the oil storage tank region in oil storage units including wing ballast tanks and cofferdams at the ends of or between oil storage tanks, the thickness of primary member webs and face-plates, hull envelope and bulkhead plating is to be not less than 7,5 mm.

2.15.2 Pump-rooms and other adjacent compartments are also to comply with *Pt 3, Ch 3, 2.15 Compartment minimum thickness 2.15.1*.

2.15.3 The minimum compartment thickness in deep draught caisson units and buoys will be specially considered but is not to be less than 7,5 mm.

2.15.4 The compartment minimum thickness is to comply with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 9, 10 Construction details and minimum thickness* of the Rules for Ships for other surface type units.

■ *Section 3*
Hazardous areas and ventilation

3.1 General

3.1.1 For the application of hazardous area classification and related ventilation requirements, *see Pt 7, Ch 2 Hazardous Areas and Ventilation*.

3.1.2 Adequate ventilation is to be provided for all areas and enclosed compartments associated with the oil storage production and process plant. The capacities of the ventilation systems are to comply, where applicable, with the requirements of *Pt 7, Ch 2, 6 Ventilation*, or to an acceptable Code or Standard adapted to suit the marine environment and taking into account any additional requirements which may be necessary during start-up of the plant.

3.1.3 Ventilation in the vicinity of mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.4 For units using oil-based mud, the tanks are to be provided with special ventilation arrangements, and for open systems, the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4*
Pollution prevention

4.1 General

4.1.1 Sumps and savealls are to be provided at potential spillage points, and drainage systems are to have adequate capacity and be designed for ease of cleaning.

4.1.2 Production manifolds are to be located and installed so that in the event of leakage in an enclosed area, a leakage detection and shut-down system will be activated. In open areas, arrangements are to be such that oil spillage will be contained, and that suitable drainage and recovery provisions are made.

4.1.3 Maintenance of production and process systems and equipment is to be governed by a permit-to-work system with rigid control on spillage prevention when opening up or testing is being carried out.

4.1.4 The arrangements for the onboard storage, and the disposal, of bilge and effluent from the production and process plant areas and spaces are to be submitted for consideration.

4.1.5 Oily water treatment systems are to have sufficient capacity for treatment of bilge and effluent water from the production and process plant areas and spaces.

4.1.6 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil and oily residue into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.7 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.8 Pollution prevention arrangements are to be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the areas of operation as applicable.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to accommodation and offshore support units as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations* whose primary function is to provide support services to offshore installations. Self-elevating accommodation units which are unmanned in transit conditions need not comply with *Pt 3, Ch 4, 3 Bilge systems and cross-flooding arrangements for accommodation units*.

1.1.2 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.3 The requirements for fire-fighting units are given in *Pt 3, Ch 5 Fire-fighting Units*.

1.1.4 Support vessels which have a diving complex on board are to have the diving installation approved in accordance with LR's *Rules and Regulations for the Construction and Classification of Submersibles and Underwater Systems* or an acceptable standard.

1.1.5 When accommodation units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production installations, it is the responsibility of the Owner/Operator to comply with the relevant regulations of the National Administrations in the country of registration and/or the area of operation, as applicable. Special consideration will be given to the safety requirements for classification purposes, *see Pt 1, Ch 2 Classification Regulations*.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 Class notations for fire-fighting units are to be in accordance with *Pt 3, Ch 5 Fire-fighting Units*.

1.2.3 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations, as appropriate:

- Accommodation unit.
- Crane unit.
- Diving support unit.
- Support unit.
- Multi-purpose support unit.
- Pipe laying unit.

1.2.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Classification Committee.

1.2.5 Support units engaged in more than two functions may be assigned the type notation multi-purpose support unit.

1.2.6 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment*, *see also Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.2.7 When the type notation Crane unit is assigned to a unit, the main deck lifting appliances on the unit are considered to form an essential feature and therefore are to be included in the class.

1.2.8 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation **LA** will be assigned, *see Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.2.9 Other special features class notations associated with lifting appliances may be assigned, see *Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Strength of structure for accommodation.
- Supports for accommodation modules.
- Structure in way of diving installations.
- Structure in way of cranes.
- Structure in way of pipe laying equipment.
- Bilge systems and cross-flooding arrangements on accommodation units.
- Electrical installations on accommodation units.

1.4 Installation layout and safety

1.4.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.4.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see Pt 1, Ch 2, 1 Conditions for classification* and *Pt 7, Ch 3 Fire Safety*.

1.4.3 Additional requirements for safety and communication systems are given in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

1.5 Plans and data submission

1.5.2 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by *Pt 3, Ch 1, 2 Information required* and *Pt 4, Ch 1, 4 Information required*, the following additional plans and information are to be submitted as applicable:

- Structural plans of the accommodation including deckhouses and modules.
- Design calculations for containerised modules.
- Module support frames or skids and details of attachments.
- Structural arrangements and supports under diving installations.
- Structural arrangements in way of crane supports.
- Structural arrangements and supports under pipe laying equipment.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of *Pt 4 STEEL UNIT STRUCTURES*, taking into account the applied weights and forces due to the accommodation, diving installations, pipe laying equipment and cranes, and the local structure is to be suitably reinforced. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The scantlings of structural deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*.

2.2.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.2.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by *Pt 3, Ch 4, 2.2 General 2.2.2*.

2.2.5 The structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of *Pt 4, Ch 6, 9 Superstructures and deckhouses*, taking into account the unit's motions and marine environmental aspects.

2.2.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_{H} in any direction as follows:

F_{H} = W sin $\boldsymbol{\theta}$ N (tonne-f)

where

$\boldsymbol{\theta}$ = 25° for semi-submersible units

$\boldsymbol{\theta}$ = 17° for self-elevating units

W = weight of the modules supported in N (tonne-f).

2.2.7 In the emergency static condition defined in *Pt 3, Ch 4, 2.2 General 2.2.6* the permissible stress levels are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*

2.3 Watertight and weathertight integrity

2.3.1 The general requirements for watertight and weathertight integrity are to be in accordance with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

■ *Section 3*
Bilge systems and cross-flooding arrangements for accommodation units

3.1 Application

3.1.1 The requirements of this Section are only applicable to units with accommodation for more than 12 persons who are not crew members. For self-elevating units, *see also Pt 3, Ch 4, 1.1 Application 1.1.1*.

3.2 Location of bilge main and pumps

3.2.1 The general requirements of *Pt 5, Ch 12 Piping Design Requirements* and *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures* are to be complied with as applicable unless otherwise specified in this Section.

3.2.2 The bilge main is to be arranged so that no part is situated nearer to the side of the unit than the damage penetration zone.

3.2.3 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the damage penetration zone, a non-return valve is to be fitted at the pipe connection junction with the bilge main.

3.2.4 The emergency bilge pump and its connections to the bilge main are to be situated inboard of the damage penetration zone.

3.2.5 At least three power bilge pumps are to be provided. Where practicable, these pumps are to be placed in separate watertight compartments which will not be readily flooded by the same damage. In units where engines and auxiliary machinery are located in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments.

3.2.6 The bilge pumping units are to be such that at least one power pump will be available in all circumstances in which the unit may be flooded after damage. This requirement will be satisfied if:

(a) one of the pumps is an emergency pump of the submersible type having a source of power situated above the bulkhead deck or maximum anticipated damage load line; or

(b) the pumps and their power sources are located throughout the length of the unit so that, under any conditions of flooding that the unit is required to withstand by Statutory Regulation, at least one pump in an unaffected compartment will be available.

3.3 Arrangement and control of bilge system valves

3.3.1 The valves and distribution boxes associated with the bilge pumping system are to be arranged to enable any one of the bilge pumps to pump out any compartment in the event of flooding. All the necessary valves for controlling the bilge suctions are to be capable of being operated from above the bulkhead deck or maximum anticipated damage load line. The controls for these valves are to be clearly marked and a means provided at their place of operation to indicate clearly whether they are open or closed.

3.3.2 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of pumping out any compartment under flooding conditions. In this case, only the valves necessary for the operation of this emergency system need to be operable from above the bulkhead deck or maximum anticipated damage load line.

3.4 Prevention of communication between compartments in the event of damage

3.4.1 Provision is to be made to prevent any compartment served by a bilge suction pipe being flooded in the event of the pipe being damaged by collision or grounding in any other compartment. For this purpose, where any part of the pipe is situated outboard of the damage penetration zone, or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5 Cross-flooding arrangements

3.5.1 Cross-flooding arrangements are not permitted as a means of attaining the damage stability criteria in accordance with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

3.5.2 Cross-flooding arrangements may be used under control to restore a situation after damage. Such arrangements are not to be automatic or self-acting. Controls are to be situated above the worst anticipated damage waterline.

■ *Section 4*
Additional requirements for the electrical installation

4.1 General

4.1.1 In general, electrical installations are to comply with the requirements of *Pt 6, Ch 2 Electrical Engineering*.

4.1.2 The requirements of this Section are applicable to units with accommodation for more than 50 persons, who are not crew members.

4.2 Emergency source of electrical power

4.2.1 A self-contained emergency source of electrical power is to be provided.

4.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, where fitted on surface type units.

4.2.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A (*see Pt 7, Ch 3 Fire Safety*) will not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A, *see Pt 7, Ch 3 Fire Safety*, and those spaces containing the

main source of electrical power, associated transforming equipment, if any, or the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

4.2.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

4.2.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 36 hours, emergency lighting:

- (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
- (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
- (iii) in the machinery spaces and main generating stations including their control positions;
- (iv) in all control stations, machinery control rooms, and at each main and emergency switchboard;
- (v) at all stowage positions for fireman's outfits;
- (vi) at the steering gear;
- (vii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors;
- (viii) at every survival craft, muster and embarkation station;
- (ix) over the sides to illuminate the area of water into which survival craft are to be launched;
- (x) on helicopter decks.

(b) For a period of 36 hours:

- (i) the navigation lights, other lights and sound signals required by the *International Regulations for the prevention of Collisions at Sea*, in force;
- (ii) the radio communications as required by Amendments to *Chapter IV - Radiocommunications* as applicable;
- (iii) the navigational aids as required by Amendments to *Regulation 19 - Carriage requirements for shipborne navigational systems and equipment*as applicable;
- (iv) general alarm and communication systems as required in an emergency;
- (v) intermittent operation of the daylight signalling lamp and the unit's whistle;
- (vi) the fire and gas detection systems and their alarms;
- (vii) emergency fire pump; the automatic sprinkler pump, if any; and the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;
- (viii) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;
- (ix) on column-stabilised units; ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system and the largest single ballast pump;
- (x) abandonment systems dependent on electric power.

(c) For a period of 24 hours:

- (i) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
- (ii) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangements, if electrically controlled, unless it has an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 24 hours.

(d) The steering gear for the period of time required by *Pt 5, Ch 19, 6 Emergency power*.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures.

(f) For a period of half an hour:

- (i) any watertight doors if electrically operated together with their control, indication and alarm circuits;
- (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency.

4.2.6 The emergency source of electrical power may be either a generator or an accumulator battery, which are to comply with the following:

(a) Where the emergency source of electrical power is a generator, it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed-cup test) of not less than 43°C;

(ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5* are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and

(iii) provided with a transitional source of emergency electrical power according to *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.7*.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:

(i) carrying the emergency electrical power without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.7*.

4.2.7 The transitional source of emergency electrical power required by *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.6* is to consist of an accumulator battery suitably located for use in an emergency, which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:

(a) For half an hour:

(i) the lighting required by *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5* and *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5*;

(ii) all services required by *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5*, *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5* and *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5* unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(b) Power to operate the watertight doors at least three times, (i.e., closed-open-closed), against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by *Pt 3, Ch 4, 4.2 Emergency source of electrical power 4.2.5*.

4.2.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

4.2.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

4.2.10 No accumulator battery except for engine starting, fitted in accordance with this Section, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

4.2.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

4.2.12 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made where necessary to disconnect automatically nonemergency circuits from the emergency switchboard to ensure that power will be available to the emergency circuits.

4.2.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to mobile offshore units intended for fire-fighting operations and are additional to those applicable in other Parts of the Rules.

1.1.2 A unit provided with fire protection and firefighting equipment in accordance with these Rules will be eligible for an appropriate class notation.

1.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the fire-fighting unit is intended to operate.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 Units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class notations as applicable:

Fire-fighting unit 1 (total monitor discharge capacity in brackets).
Fire-fighting unit 2 (total monitor discharge capacity in brackets).
Fire-fighting unit 3 (total monitor discharge capacity in brackets).
Fire-fighting unit 1 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 2 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 3 (total monitor discharge capacity in brackets) with water spray.

1.2.3 The notation **Fire-fighting unit 1** or **Fire-fighting unit 2** or **Fire-fighting unit 3** signifies that a unit complies with these Rules and is provided with the appropriate firefighting equipment described in *Pt 3, Ch 5, 1.2 Class notations 1.2.3*, with the total discharge capacity of monitors in m^3/h shown in brackets.

Table 5.1.1 Fire-fighting equipment

Equipment	Fire-fighting unit		
	1	2	3
Minimum total pump capacity, m^3/h	2400	7200	10000
Minimum number of water monitors	2	3	4
Minimum discharge rate per monitor, m^3/h	1200	1800	1800
Minimum height of trajectory of jets of monitors above sea level, metres	45	70	70
Minimum range of monitor jets, metres	120	150	150

Minimum fuel capacity for monitors, hours	24	96	96
Number of hose connections each side of unit	4	8	8
Number of fireman's outfits	4	8	8

1.2.4 The addition of the words **with water spray** to the notations referred to in *Pt 3, Ch 5, 1.2 Class notations 1.2.3* signifies that a unit is provided with a water spray system which will provide an effective cooling spray of water over the vertical surfaces of the unit to enable it to approach a burning installation for firefighting purposes. The requirements for such a system are set out in *Pt 3, Ch 5, 4 Fire protection*.

1.2.5 Support units may be assigned additional class type notations when appropriate, *see Pt 3, Ch 4, 1.2 Class notations*.

1.3 Surveys

1.3.1 The requirements for surveys are given in *Pt 7, Ch 3, 1.3 Surveys* of the Rules for Ships, which are to be complied with where applicable.

1.4 Plans and data submission

1.4.1 The requirements for submission of plans are given in *Pt 7, Ch 3, 1.4 Submission of plans* of the Rules for Ships, which are to be complied with where applicable.

1.5 Definitions

1.5.1 The requirements for definitions are given in *Pt 7, Ch 3, 1.5 Definitions* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 2* Construction

2.1 General

2.1.1 The requirements for construction are given in *Pt 7, Ch 3, 2 Construction* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 3* Fire-extinguishing

3.1 General

3.1.1 The requirements for fire-extinguishing are given in *Pt 7, Ch 3, 3 Fire-extinguishing* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 4* Fire protection

4.1 General

4.1.1 The requirements for fire protection are given in *Pt 7, Ch 3, 4 Fire protection* of the Rules for Ships, which are to be complied with where applicable.

■ Section 5
Lighting

5.1 General

5.1.1 The requirements for lighting are given in *Pt 7, Ch 3, 5 Lighting* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 1* Scope

1.1 General

1.1.1 The following requirements are for units intended for operations in ice and cold conditions.

1.1.2 Guidance on the appropriate requirements and notations is provided in *Pt 3, Ch 6, 1.1 General 1.1.2*.

Table 6.1.1 Ice and cold operations

<table>
<tr><td colspan="3">Reference</td><td>Conditions</td><td>Description</td><td>Notation</td></tr>
<tr><td colspan="6">Ice Operations</td></tr>
<tr><td rowspan="9">Rules for Ships,
Pt 8, Ch 2 Ice Operations - Ice Class</td><td>Section 1</td><td></td><td>Application</td><td></td><td></td></tr>
<tr><td>Section 2</td><td>Hull</td><td rowspan="2">General requirements</td><td rowspan="2">Applicable to all ice classes</td><td rowspan="2"></td></tr>
<tr><td>Section 3</td><td>Machinery</td></tr>
<tr><td>Section 4</td><td>Hull</td><td rowspan="2">Light and very light ice conditions</td><td>For ships with length less than 150 m</td><td>Ice Class 1E</td></tr>
<tr><td>Section 5</td><td>Machinery</td><td>Hull strengthening in forward region only</td><td>Ice Class 1D</td></tr>
<tr><td>Section 6</td><td>Hull</td><td rowspan="4">First-year ice conditions</td><td rowspan="2">Finnish-Swedish Ice Class Rules</td><td rowspan="2">Ice Class 1C FS
Ice Class 1B FS
Ice Class 1A FS
Ice Class 1AS FS</td></tr>
<tr><td>Section 7</td><td>Machinery</td></tr>
<tr><td>Section 8</td><td>Hull</td><td rowspan="2">Finnish-Swedish Ice Class Rules with enhanced engine power for icebreaking capability</td><td>Ice Class 1C FS(+)
Ice Class 1B FS(+)</td></tr>
<tr><td>Section 9</td><td>Machinery</td><td>Ice Class 1A FS(+)
Ice Class 1AS FS(+)</td></tr>
</table>

	Section 10	Hull			**Ice Class PC7**
					Ice Class PC6
					Ice Class PC5
	Section 11	Machinery	Multi-year ice conditions	IACS Polar Ship Rules	**Ice Class PC4**
					Ice Class PC3
					Ice Class PC2
					Ice Class PC1
Cold Operations					
	Section 1		Application		
Provisional Rules for the Winterisation of Ships	Section 2	Hull materials	Low temperature operations	Hull construction materials	**Winterisation H(t)**
	Section 3	Equipment and systems	Low temperature operations	Short duration	**Winterisation C(t)**
				Seasonal duration	**Winterisation B(t)**
				Prolonged duration	**Winterisation A(t)**

■ *Section 2* Ice Environment

2.1 General

2.1.1 This Section is intended to give assistance on the selection of a suitable ice class notation for the operation of units in ice-covered regions.

2.1.2 The Owner is to confirm which notation is most suitable for their requirements. Ultimately, the responsibility rests with the Operator of the unit and their assessment of the ice and temperature conditions at the time.

2.1.3 The documentation supplied to the unit is to contain the ice class notation adopted, any operation limits for the unit and guidance on the type of ice that can be navigated for the nominated ice class.

2.2 Definitions

2.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in *Pt 3, Ch 6, 2.2 Definitions 2.2.1*.

Table 6.2.1 WMO definition of ice conditions

Ice conditions	Ice thickness
Medium first-year	1,2 m
Thin first-year, second stage	0,7 m
Thin first-year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

2.2.2 *Pt 3, Ch 6, 2.2 Definitions 2.2.2* defines the ice classes in relation to the Rules and the equivalent internationally recognised Standards.

Table 6.2.2 Comparison of ice standards

Lloyd's Register class notation	Finnish-Swedish Ice Class	Canadian type
Ice Class 1AS FS(+) **Ice Class IAS FS**	IA Super	A
Ice Class 1A FS(+) **Ice Class 1A FS**	IA	B
Ice Class 1B FS(+) **Ice Class 1B FS**	IB	C
Ice Class 1C FS(+) **Ice Class 1C FS**	IC	D
Ice Class 1D	—	D
Ice Class 1E	—	E

2.3 Application

2.3.1 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice floes and the ice edge for each season. *See Pt 3, Ch 6, 2.5 National Authority requirements 2.5.4* to *Pt 3, Ch 6, 2.5 National Authority requirements 2.5.4* and *Pt 3, Ch 6, 2.5 National Authority requirements 2.5.4*.

2.3.2 Operation with**Ice Class 1C FS** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with **Ice Class 1A FS** may be possible up to 150 nm inside the medium first-year ice shown depending on the severity of the winter. Operation up to the multi-year ice is possible most years with **Ice Class 1AS FS**.

2.3.3 Operation in the region between 7/10 and 1/10 in the ice-covered regions is possible with due care for units with no ice class. For units operating for extended periods in these areas, it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for non-ice class units, the material requirements of *The Provisional Rules for the Winterisation of Ships* are recommended.

2.4 Ice Class notations

2.4.1 Where the requirements of *Pt 8, Ch 2 Ice Operations - Ice Class* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are complied with, the unit will be eligible for a special features notation, *see also Pt 3, Ch 6, 1.1 General 1.1.2*.

2.5 National Authority requirements

2.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. *Pt 3, Ch 6, 2.2 Definitions 2.2.2* gives the equivalence of National Authority requirements.

2.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice Classes given in *Pt 3, Ch 6, 2.2 Definitions 2.2.2*.

2.5.3 Units intending to navigate in the Canadian Arctic must comply with the Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353, in respect of which Lloyd's Register is authorised to issue Arctic Pollution Prevention Certificates.

2.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

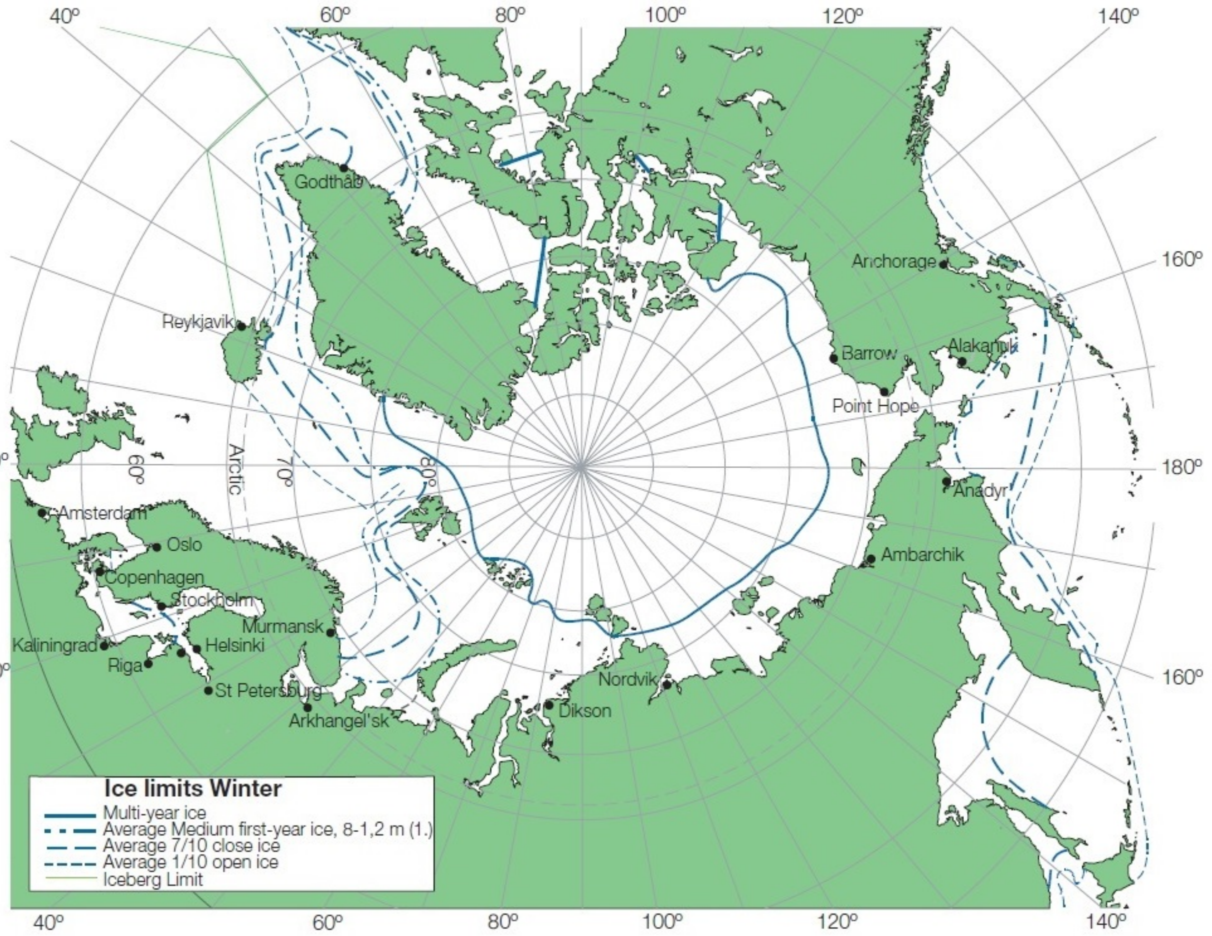


Figure 6.2.1 Ice Limits for the Arctic Winter

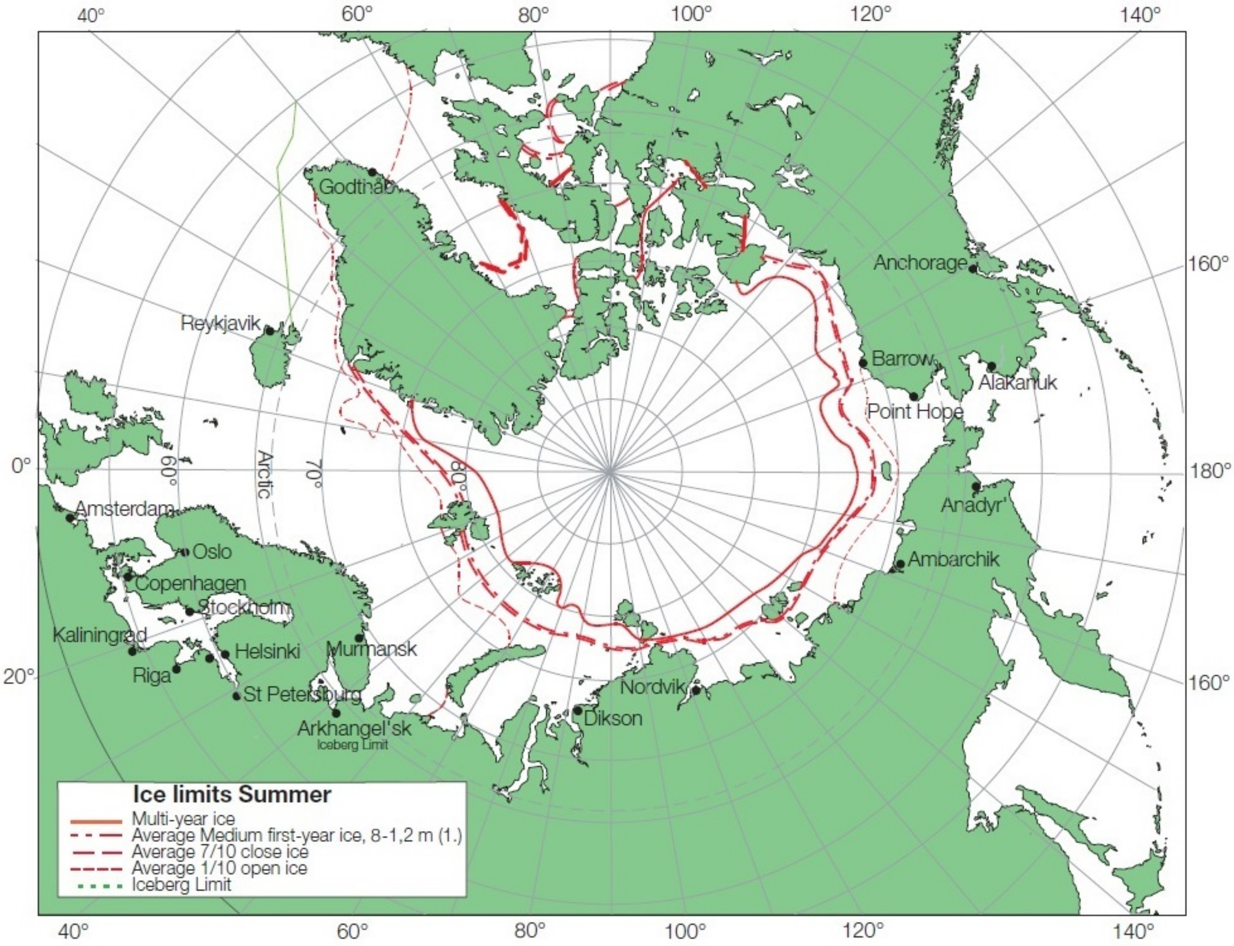


Figure 6.2.2 Ice Limits for the Arctic Summer

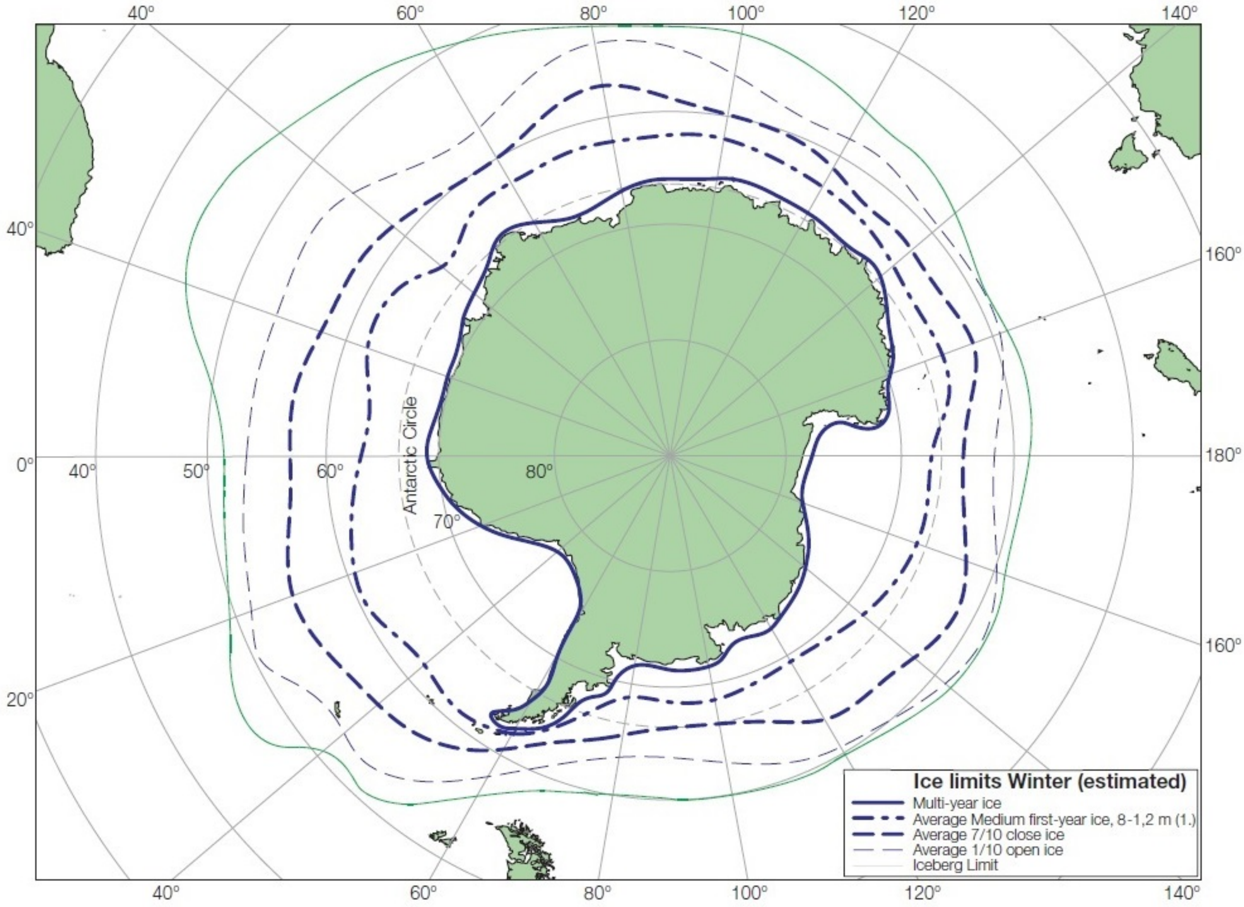


Figure 6.2.3 Ice Limits for the Antarctic Winter

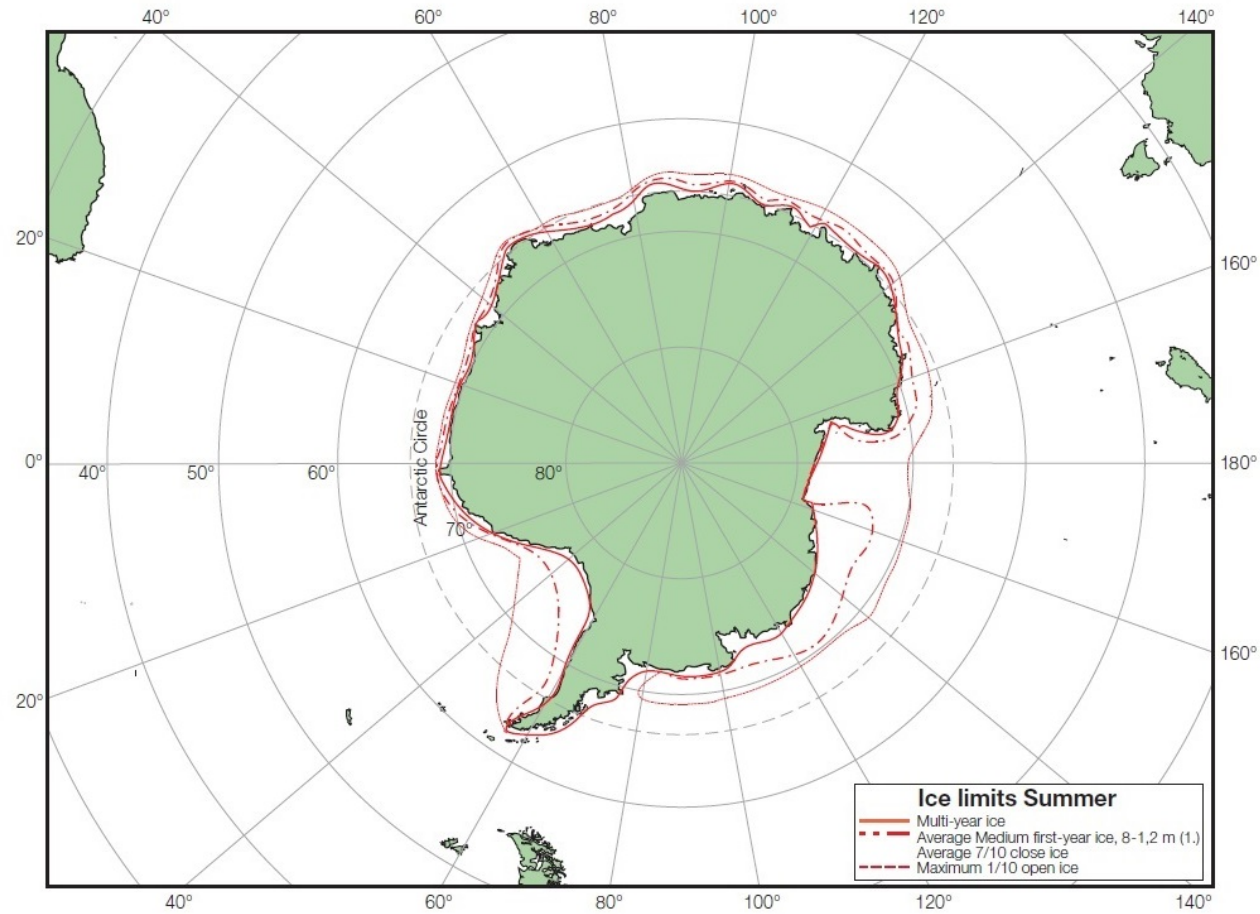
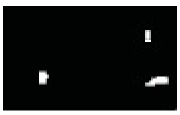
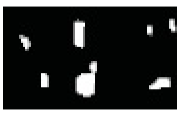
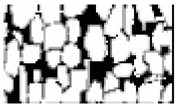
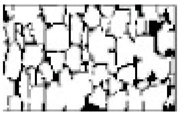
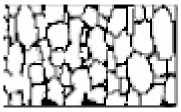
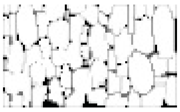


Figure 6.2.4 Ice Limits for the Antarctic Summer

Table 6.2.3 Concentration of ice

Free ice	 0/10		
Open water	 < 1/10		
Very open drift	 1/10	 2/10	 3/10

Open drift	 4/10	 5/10	 6/10
Close pack/drift	 7/10	 8/10	
Very close pack	 9/10	 9+/10	
Compact/consolidated ice	 10/10		

2.6 Ice conditions

2.6.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the worldwide web at: www.natice.noaa.gov.

2.6.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their website can be found at: www.ice-glaces.ec.gc.ca.

■ *Section 3*
Air Environment

3.1 Air temperature

3.1.1 For units intended to operate in cold regions, the temperature on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

3.1.2 The average external design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years

Average = average during one day and one night

Lowest = lowest during the year

MDHT = Mean Daily High Temperature

MDAT = Mean Daily Average Temperature

MDLT = Mean Daily Low Temperature

Pt 3, Ch 6, 3.1 Air temperature 3.1.4 shows the definition graphically.

3.1.3 The lowest external design air temperature is to be taken as the lowest mean daily lowest air temperature in the area of operation. Where reliable environmental records for contemplated operational areas exist, the lowest external design air temperature may be obtained after the exclusion of all recorded values having a probability of occurrence of less than 3 per cent.

3.1.4 Lowest mean daily average air temperatures for the Arctic and Antarctic are provided in *Pt 3, Ch 6, 3.1 Air temperature 3.1.4* to *Pt 3, Ch 6, 3.1 Air temperature 3.1.4*.

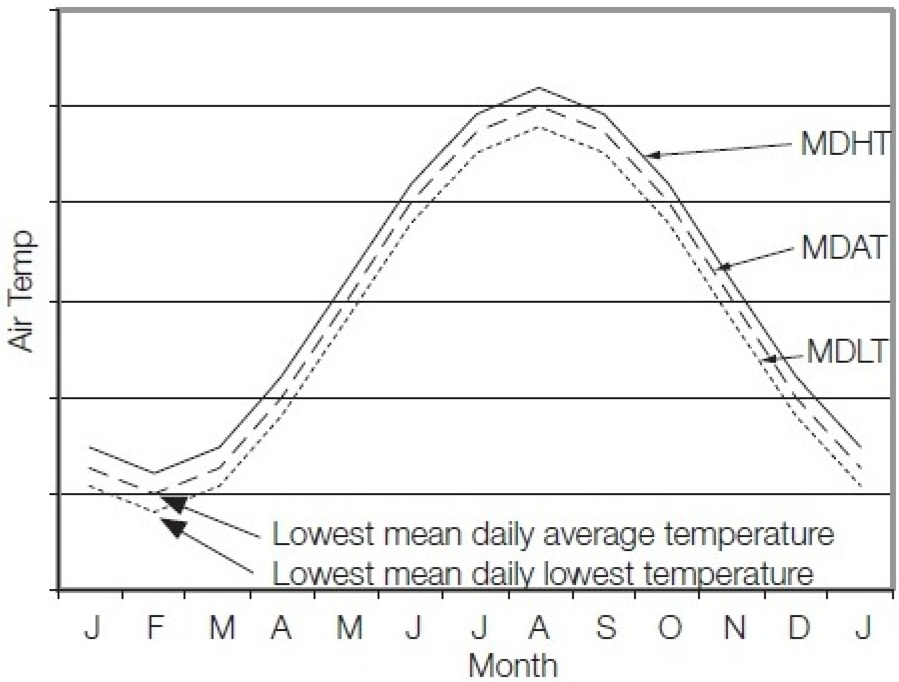


Figure 6.3.1 Air temperature

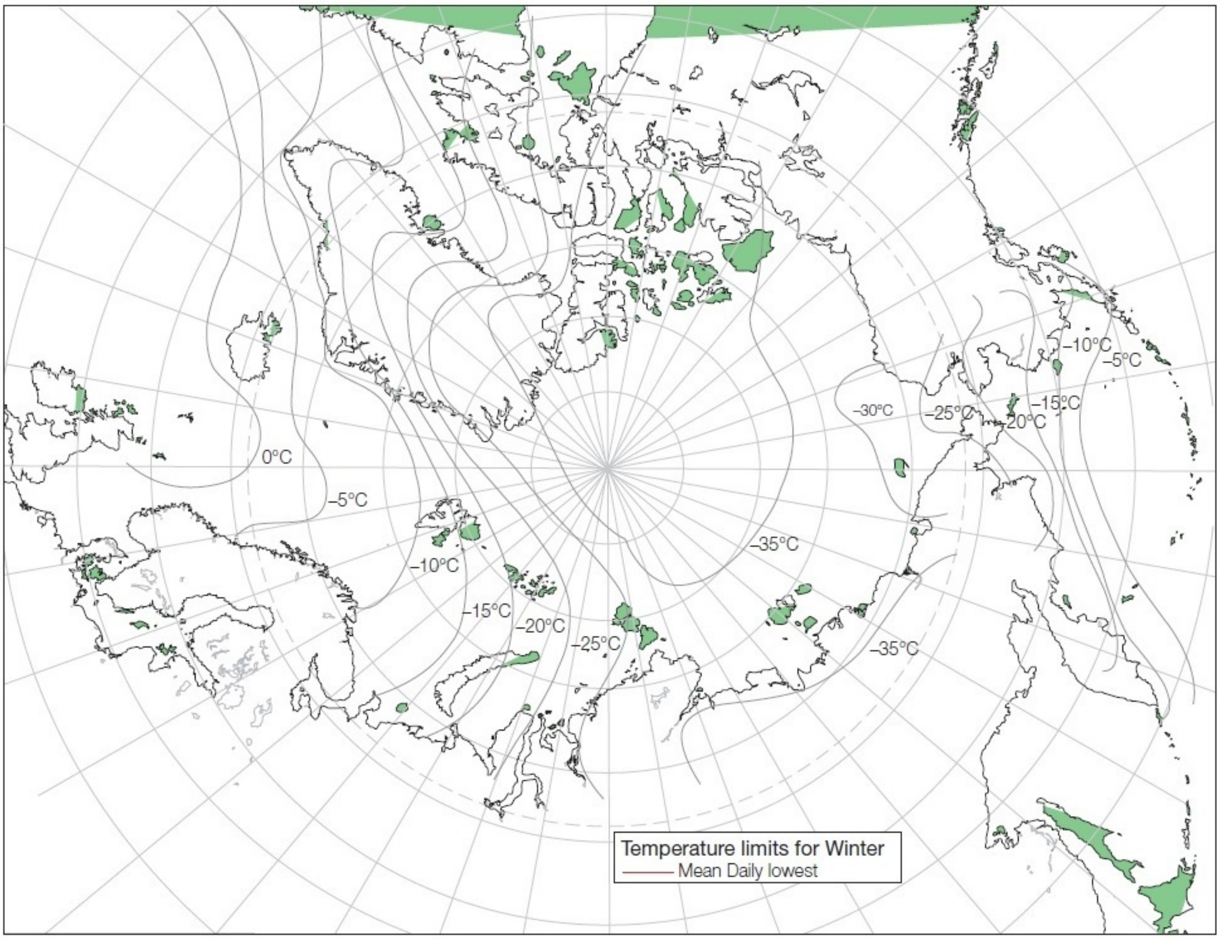


Figure 6.3.2 Lowest mean daily average air temperatures for the Arctic

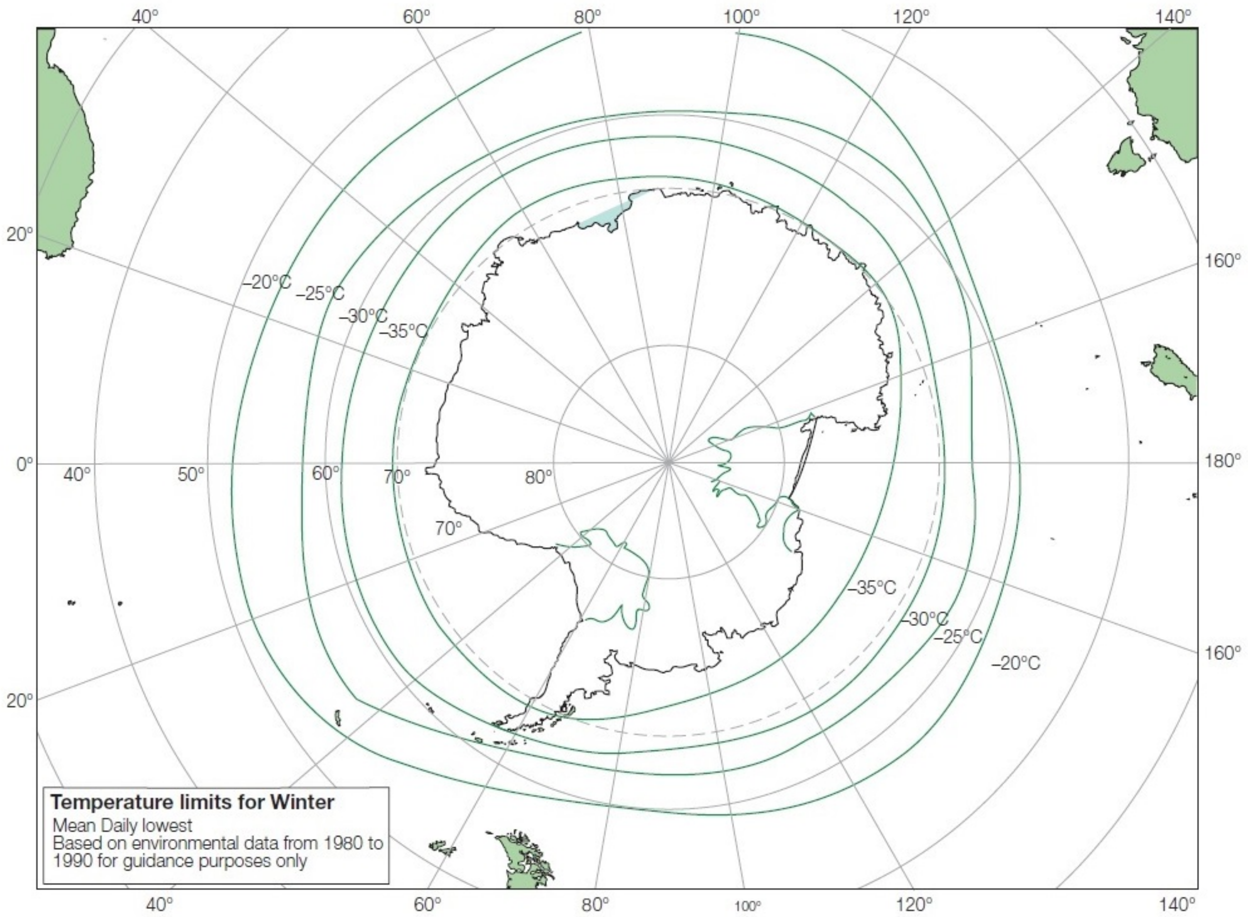


Figure 6.3.3 Lowest mean daily average air temperatures for the Antarctic

■ *Section 4* Icing Environment

4.1 Ice accretion

4.1.1 For units intended to operate in cold regions, the build-up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

4.1.2 Icing is to be considered for units operating in the following areas, *see Pt 3, Ch 6, 4.1 Ice accretion 4.1.2* and *Pt 3, Ch 6, 4.1 Ice accretion 4.1.2*.

- The area north of latitude 65°30’N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30’N, longitude 15°E, north of latitude 73°30’N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in sub-paragraphs above.

- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

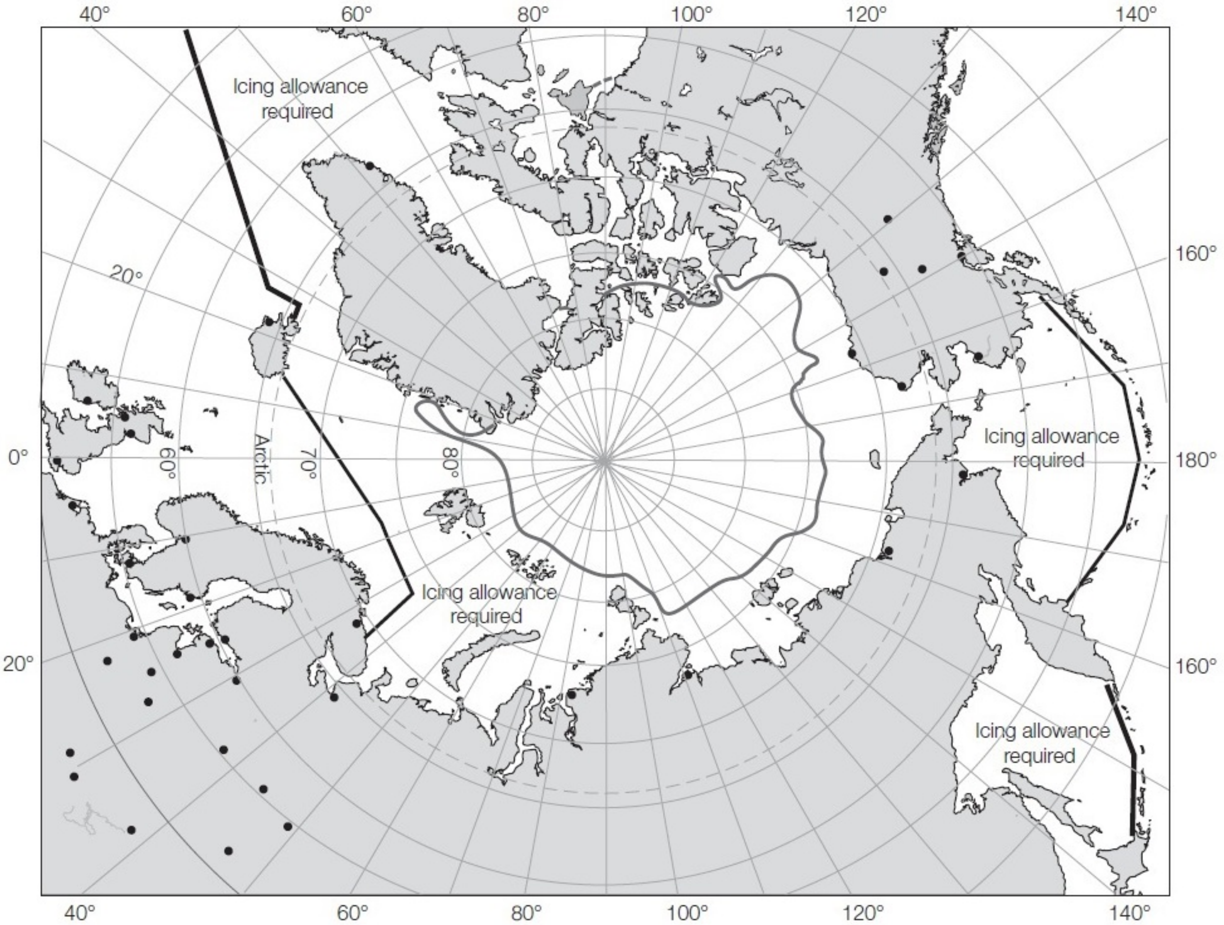


Figure 6.4.1 Ice accretion limits for the Arctic

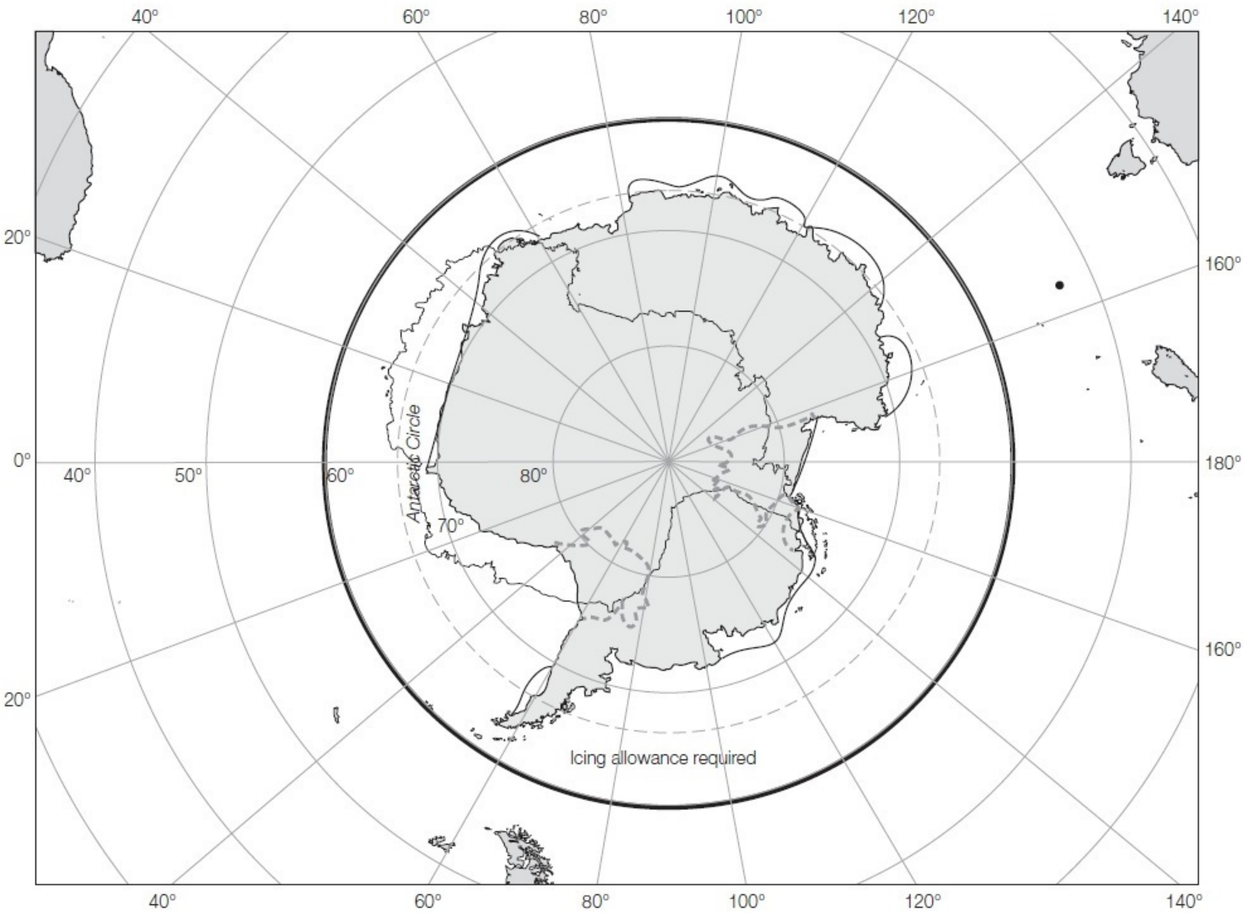


Figure 6.4.2 Ice accretion limits for the Antarctic

■ Section 5
Strengthening standard for navigation in ice – Application of requirements

5.1 Additional strengthening

5.1.1 When disconnectable units are required to navigate in ice and additional strengthening is fitted in accordance with the requirements given in this Chapter, an appropriate special features notation will be assigned. It is the responsibility of the Owners to determine which notation is most suitable for their requirements.

5.1.2 For semi-submersible units with twin lower hulls the ice strengthening, as required by this Chapter, is to be carried out to both hulls. Where the exposed deck of the lower hulls is situated below the upper limit of the ice belt, the strengthening of the deck will be subject to special consideration and the deck thickness is not to be less than the shell plating in the main ice belt.

5.1.3 The extent of reinforcement on units of unconventional form will be specially considered.

5.2 Plans and data submission

5.2.1 Plans, calculations and data are to be submitted as required by the relevant Parts of these Rules together with the additional information required by *Pt 8 Rules for Ice and Cold Operations* of the Rules for Ships.

Section 6
Strengthening requirements for navigation in ice

6.1 General

6.1.1 The strengthening requirements for navigation in ice are given in *Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships which are to be complied with where applicable.

6.1.2 The requirements for strengthening for navigation in ice as given in *Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships are intended for ships of conventional designs and arrangements. Units considered outside this applicability will be specially considered by LR and may require additional strengthening and structural analysis for the primary structure by direct calculation, or experimental verification. *See also* limits to the ship length and hull form contained in the engine power requirement in the *Finnish-Swedish Ice Class Rules* and icebreaking bow form for the *Polar Ship Rules*.

6.1.3 The requirements for strengthening for navigation in ice as given in *Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships are intended for ships operating in typical ice voyages and harbour operations. The operation of units may require a rational analysis for determining the maximum operating ice pressures on the structure based on acceptable environmental data such as the design ice conditions, e.g., multi-year ice floe size and concentration, or whether assistance from icebreakers is anticipated.

6.1.4 When a unit operates in areas where there is the possibility of collision with icebergs, appropriate data is to be submitted and the structure suitably strengthened for the collision loads.

6.1.5 Special requirements will be required for sea inlet chests for machinery cooling and fire pump suctions and reference should be made to the relevant text of *Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships. The design and arrangement of sea inlet chests will be specially considered as applicable to the type of unit.

Section 7
Operation in ice conditions at a fixed location

7.1 General requirements

7.1.1 When a unit is required to operate at a fixed location in ice conditions, the designer/Builder is required to submit a rational analysis for determining the maximum operating ice pressures on the structure based on acceptable environmental data.

7.1.2 The minimum design temperature of the structure and steel grades will be specially considered, *see also Pt 4, Ch 2 Materials*.

7.1.3 The extent of additional strengthening will be specially considered by LR and additional structural calculations for the primary structure will be required.

7.1.4 When a unit operates in areas where there is the possibility of collision with icebergs, appropriate data is to be submitted and the structure suitably strengthened for the collision loads.

7.1.5 Special requirements will be required for sea inlet chests for machinery cooling and fire pump suctions and reference should be made to the relevant text of *Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships. The design and arrangement of sea inlet chests will be specially considered as applicable to the type of unit.

7.1.6 When a unit has been reinforced and approved by LR for operating in ice, a suitable descriptive note will be included in the Class Direct website.

Section 8
Ice accretion and low temperatures

8.1 General requirements

8.1.1 For units intended to operate in cold regions, the build-up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

8.1.2 When units are fitted with riser systems the arrangements are to be designed to minimise the effect of ice loadings on the risers.

8.1.3 Suitable steam generating equipment or an equivalent means is to be provided, with outlets and hoses, to keep designated areas free of ice and snow such that operation and inspection/maintenance may be conducted safely. Such equipment is to be capable of being used in at least the following locations:

- The working areas.
- The helicopter deck.
- Walkways and escape routes.
- Lifeboat embarkation station.

8.1.4 In the case of self-elevating units where the design of the elevating machinery is required to operate in ice conditions, suitable de-icing equipment is to be provided.

8.1.5 The starting requirements of the emergency generators for low temperature operation is to be in accordance with *Pt 5, Ch 2 Reciprocating Internal Combustion Engines* of the Rules for Ships.

8.1.6 Electrical equipment and cables likely to be exposed to sustained low temperatures are to be suitably constructed for the ambient conditions in accordance with a recognised National or International Standard.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the drilling plant, derricks and flare structures, etc., and drilling related systems and equipment installed on board drilling units. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the approval of the drilling plant which includes the equipment and systems required for safe drilling operations but limited to those aspects defined in *Pt 3, Ch 7, 1.3 Scope*. The approval of the equipment includes all mechanical and structural components of the drilling plant covered by the Rules. The Rules also cover the protection of the environment with regard to pollution.

1.1.3 The operational aspects and reliability of the drilling plant are not covered by class except when they have an effect on the overall safety of the drilling unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that units with an installed drilling plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval. The drilling facilities are to be considered designed to operate under ambient conditions prevalent in the intended area of operation, and based on relevant MetOcean and climatic data.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the drilling plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit's Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference is to be made.

1.2.2 Units fitted with an installed drilling plant facility which complies with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.3 When a unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.2.4 The latest issue of the following referenced standards is to be used unless otherwise agreed beforehand. Other recognised Standards may be used provided it can be shown that they meet or exceed the requirements of the referenced standards in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. When other codes or standards are proposed, gap analysis and risk assessments are to be provided by the dutyholder to demonstrate an equivalent level of safety to the recognised Standards in this notation.

1.3 Scope

1.3.1 Goal:

(a) The drilling plant is to be designed, constructed, installed and maintained satisfactorily for the intended service conditions in order to minimise the risk to the unit, personnel on board and to the environment. The drilling plant is to be operated and maintained by competent personnel.

(b) All drilling plants, regardless of design, are to comply with this goal. The prescriptive requirements in this Section are considered to provide a route to meeting this goal. Alternative arrangements which are considered by LR also to meet this goal will be accepted.

(c) Apart from other hazards noted elsewhere in these Rules, examples of some hazards specifically related to drilling operations are as follows:

- Blow out.
- Hydrogen sulphide and other toxic gases.
- Uncontrolled release of hydrocarbon gases.
- Loss of position.
- Fire or explosion.
- Loss of positive pressurisation in hazardous spaces or equipment.
- Ventilation in hazardous areas.
- Dropped objects.
- Failure of Zone management systems.
- Punch through (bottom supported units).
- Shallow gas (stability and fire risks).
- Radioactivity.
- Environmental spills.

Risk assessments are to be made by the dutyholder with regard to mitigating or limiting the effects of these and any other similar related hazards.

1.3.2 Any part, component or structure of the drilling system that is required to allow the rig to conduct drilling or well testing operations. This includes any outlet from hydrocarbon flares and vent systems, and includes the subsea blow out preventer stack, risers, conductors and any other subsea component that is required to allow drilling operations from the unit to be conducted but does not include subsea production equipment.

1.4 Plant design characteristics

1.4.1 The design and arrangement of the drilling plant, derricks and flare structures, etc., are to comply with the requirements of this Chapter and/or recognised Codes and Standards, *see Pt 3, Ch 7, 1.5 Recognised Codes and Standards*

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes and Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in *Pt 3, Ch 7, 1.4 Plant design characteristics 1.4.4*, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any of the following loads, as applicable:

- Static and dynamic loads due to wave-induced motions of the unit.
- Loads resulting from hull flexural effects at the plant support points, as appropriate.
- Direct wind loads.
- Normal gravity and functional loads.

- Thermal loads, as appropriate.
- Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised units:

  25° in any direction.
- Surface type units:

  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:

  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in *Pt 3, Ch 7, 1.4 Plant design characteristics 1.4.4*, the plant is to be assumed to have maximum operating weights, temperatures and pressures, unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports in transit, operating and emergency conditions are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

1.4.7 The design of the plant is to allow for adequate space and services for completion and intervention equipment, such as, but not limited to, wire line, logging, coiled tubing, snubbing, well completion, work over and well testing. The location is also to take into consideration the requirement for hazardous area classification of equipment and services. Communication and safety systems are also required to be considered in the design.

1.5 Recognised Codes and Standards

1.5.1 Installed drilling plant facilities designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner’s proposals at an early stage, in order that a basis for acceptance of the standards may be agreed. Refer to Appendix A for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the drilling plant structures and drilling related systems and equipment as defined in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. Other Codes and national Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes and Standards are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of drilling equipment is to be based on equipment categories agreed with LR.

1.6.2 Drilling equipment, including its associated pipes and valves, is to be divided into equipment categories **1A**, **1B** and **II**, depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

*1A.*Equipment of primary importance to safety for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

*1B.*Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

*II*Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. A full list of equipment categories for each drilling plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Drilling equipment is to be certified in accordance with the following requirements:

(a) Category **1A**

- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) Category **1B**

- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) Category **II**

- Supplier's/manufacturer's works' certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the drilling plant installation is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records are to include the following:

- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examination.
- Load, pressure and functional test reports.

1.9 Installation of drilling plant equipment

1.9.1 The installation of drilling equipment on board the unit is to be controlled by LR in accordance with the following principles:

- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category II equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.9.2 A test procedure, including acceptance criteria and functional description prior to the factory acceptance test of equipment, system or sub-system, is to be provided.

Mechanical completion to the satisfaction of LR is to be completed prior to starting or testing of any drilling equipment or system. The commissioning procedures are to contain all necessary information required to ensure safe start-up and shut-down of each equipment or system. All equipment and system operating and maintenance manuals are to be made available to LR before final commissioning.

The drilling package will undergo a final drilling trial before delivery, in accordance with *Pt 3, Ch 7, 11 Trials*. All drilling equipment and related systems will be required to operate simultaneously with simulated drilling loads and operate as close to the normal drilling operations design as possible. All drilling instrumentation and sensors will also be included in the trial. A guidance note on how to conduct final trials will be made available for the Owner.

1.10 Maintenance and repair

1.10.1 It is the responsibility of the Owners/Operators to ensure that installed drilling plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specifications.

1.10.2 When it is necessary to repair or replace installed drilling plant, any repaired or spare part is to be subject to the equivalent certification as the original part.

1.10.3 The design and layout of the drilling systems are to provide safe working arrangements for operation and maintenance. Use of man-riding winches or baskets for routine maintenance should be discouraged.

1.10.4 Sufficient tools and test equipment to ensure safe and continued operation of the drilling plant are to be provided. Suitable tools and equipment for working at height and for use in hazardous areas are also to be provided.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2*
Structure

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:

- General arrangement plans of the drilling plant.
- Drilling derrick structural plans and design calculations.
- Raw water towers' structural plans and design calculations.
- Flares structures' structural plans and design calculations.
- Structural plans of equipment skids, support stools and design calculations.
- Structural plans of supports to lifting appliances.

2.2 Materials

2.2.1 Materials are to comply with *Pt 3, Ch 1, 4 Materials* and material grades are to comply with *Pt 4, Ch 2 Materials* using the categories defined in this Section.

2.2.2 Support structures for the drilling plant are to be divided into the following categories:

- Primary structure.
- Secondary structure.

2.2.3 Main load-bearing members and elements subjected to high tensile or shear stresses are defined as primary structure. All other structure is considered to be secondary structure.

2.2.4 Some specific examples of structural elements which are considered as primary structure are as follows:

- Derrick legs and base plates.
- Derrick principal cross bearing.
- Derrick crown block/water table supports.
- Derrick bolts.
- Support stools (attached to the main/upper deck).
- Main legs, chords and end connections.
- Foundation bolts.

2.3 Supporting structure interfaces

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support stools, tanks and storage vessels, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.3.2 The design of supporting structures for drilling facilities is to integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the drilling plant are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength* and the local strength is to comply with *Pt 4, Ch 6 Local Strength*.

2.3.4 The BOP frame, lifting points or supports are to meet the requirements of API RP 2A-WSD.

2.4 Derrick and masts

2.4.1 The structural design of drilling derricks is to be in accordance with a recognised Code of Practice, such as API Spec 4F or acceptable equivalent, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. The design conditions defined in *Pt 3, Ch 7, 1.4 Plant design characteristics* are to be complied with.

2.4.2 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick, the effects of ice loading are to be included in the calculations, *see Pt 4, Ch 3 Structural Design*. The design criterion for this condition may be taken as a non-drilling condition with defined setback loading. The environmental criteria are to be agreed with LR, but in general may be based on five-year return criteria for the operating location.

2.4.3 The structural design of the drilling derrick may be required by LR to include the effect of fatigue loading, *see Pt 4, Ch 5 Primary Hull Strength*.

2.4.4 Fatigue damage calculations for individual components when required are to take account of the degree of redundancy and also the consequence of failure.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

(a) The design of the derrick or mast and associated ancillary equipment is to incorporate features to reduce the risk to personnel during routine maintenance or operations.
(b) The design is to allow for suitable and safe access from deck or installed work platforms for operation, maintenance and inspection services. All items in the derrick are to be accessible for routine inspection, without the need for man-riding winches.
(c) Where direct access to lubrication points such as crown or deflector sheaves cannot be provided, the use of remote grease lines can be incorporated.
(d) Portable equipment such as catwalk samson posts are also to be fitted with padeyes to allow safe removal and re-location.
(e) The design is to also allow for extra hang off points for temporary equipment such as wire line units.
(f) All padeyes are to be designed, installed and tested to LR requirements, and all padeyes are to be identified and a record book kept, allowing for inspection records to be maintained.
(g) Consideration is to be given to providing access and means to fight a major fire at the monkey board level. The means to fight a fire at this level are to include portable and fixed fire-fighting systems.
(h) Modification to any part of the derrick or mast from original design will require OEM and LR design approval, followed by trials if necessary.
(i) Temporary installed structures, members or fittings are to undergo an assessment by the dutyholder to confirm they will not affect the original design; if the design is affected, details are to be submitted for approval.
(j) Casing stabbing boards are to comply with the following requirements:

- The hoisting system is to be designed and constructed to Codes and Standards approved by LR.

- Permanent safe access to the stabbing board for operators and maintenance personnel is to be provided.
- Any rack and pinion system is to be designed so that the working platform will not fall if the rack or pinion should fail, and a single or common mode failure cannot occur.
- Where winch systems are used, the rope is to spool evenly on the drum and there are to be at least three full turns of rope remaining on the drum at all times.
- The rope is to remain captive with the drum and sheave systems under all service conditions, including slack rope conditions.
- Upper and lower-level limit switches are to ensure that the hoist system does not operate beyond its specified range.
- Casing stabbing boards is to be clearly marked ‘SUITABLE FOR CARRYING PEOPLE’ and with the number of people they can carry.
- Casing stabbing boards and other working platforms that are raised and lowered by a powered or manually operated system are to provide users with a secure and safe means of travel and support at the point of work.
- The working platform is to be positively guided by rails or runners. The guidance system is to ensure that the platform remains captive to its rails or runners under all circumstances, including any wheel or roller failure or failure of the primary hoisting system.
- Rails/runners are to be securely attached to their supports and are to not open up under static operations, travelling or other dynamic operations, overload testing or operation of the secondary control/braking system.
- The working platform is to have non-slip standing surfaces, handrails, mid-rails and edge protection.
- The platform is to also have anchorage points for inertia-type safety harnesses.
- Control of the primary lifting system is to provide smooth movement of the working platform. The control lever is to spring to neutral on release, effectively braking the primary hoisting system.
- Where a manual system of raising or lowering the platform is used, a positive locking system such as a ratchet-and-pawl mechanism is to be provided in addition to the service brake.
- A secondary, inertia-type brake, acting at the rails, is to be provided in case there is any failure in the primary hoisting system. The secondary brake is to act independently of the primary brake and not require any power source (hydraulic, electrical or pneumatic) for its operation.
- Each braking system is to be capable of holding the full rated capacity of the loaded stabbing board plus allowances for dynamic effects. It is not to be possible to lower the working platform by brake operation only. Two locking devices are to be provided, such that one locking device operates when the lifting handle is at neutral and the other one operates if the hoist mechanism fails. Each device is to be independent.
- A speed controlling device is to prevent the raising and lowering speed of the platform exceeding tripping speed.
- Adequate safety gear of the progressive type is to be provided, designed to engage within freefall conditions.
- The platform is to be equipped with a latch lock mechanism which secures it when not in motion.

2.5 Water towers

2.5.1 Water towers on self-elevating units are to be designed in accordance with a recognised Code or Standard, modified to take into account the unit’s motions and marine environmental aspects, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. Provisions for effective securing of towers when the unit is in transit is also to be similarly designed. The design conditions defined in *Pt 3, Ch 7, 1.4 Plant design characteristics* are to be complied with.

2.5.2 The structural design of the tower is to include the effect of fatigue loading, *see Pt 4, Ch 5 Primary Hull Strength*.

2.5.3 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.5.4 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.5.5 Wind loads are to be calculated in accordance with LR’s Code for Lifting Appliances in a Marine Environment (hereinafter referred to as LAME Code), or a recognised Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.5.6 The permissible stresses in the hull structure below the tower are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

2.6 Flares structures

2.6.1 Flares structures are to be designed in accordance with the requirements of a recognised Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. The design conditions defined in *Pt 3, Ch 7, 1.4 Plant design characteristics* are to be complied with.

2.6.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.6.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in *Pt 3, Ch 7, 1.4 Plant design characteristics*.

2.6.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see Pt 4, Ch 5 Primary Hull Strength*.

2.6.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.6.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.6.7 Wind loads are to be calculated in accordance with LR's LAME Code or a recognised Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.6.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

2.7 Lifting appliances

2.7.1 Lifting appliances shall, as a minimum, meet the requirements of the following Standards and are to comply with LR’s LAME Code, and where applicable, PUWER Reg 4 and LOLER Reg 5. *See also Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

API Spec 2C. Specification for offshore pedestal mounted cranes.

API RP 2D. Operation and maintenance of offshore cranes.

ASME B30.20. Below-the-hook lifting devices.

BOP handling systems will meet the minimum requirements of API Spec 7K.

Hoisting appliances are to be located such as to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

Submitted design data for hoisting appliances is to include all load and hoisting/lowering speed combinations at the rope drum.

Man-riding winches are to be of an approved type and certified for offshore use, and they are to comply with the following requirements:

(a) Two fail safe brakes are to be provided, one automatic and the other manual.
(b) Hydraulic winches may be provided with a regenerative brake system with breaking valve, in place of a secondary manual brake.
(c) The operating lever is to be returned to neutral upon release in any position.
(d) Declutching devices are not to be fitted, unless otherwise agreed by LR, *see Pt 3, Ch 7, 2.7 Lifting appliances 2.7.1*.
(e) ‘Sprag’ type unidirectional bearings (freewheels) are acceptable subject to regular satisfactory in-service inspection.
(f) Lowering under normal operating conditions is to be through control of the motor.
(g) Means for prevention of overriding and underriding of the winch is to be provided, where reasonably practicable.
(h) Manufacturer’s label indicating operational parameters and approval for man-riding.
(i) A sign affixed to the winch, clearly indicating suitability for man-riding (for example, ‘SUITABLE FOR MANRIDING’).
(j) The winch operating lever must automatically return to neutral when released.
(k) An automatic brake that will engage upon returning the operating lever to neutral.
(l) A manual brake.
(m) A guide for spooling the wire rope onto the drum (manual or automatic).
(n) The ability to lower the rider in a controlled manner in the event of loss of power to the winch.
(o) An emergency disconnect from the power source (ESD) located within winch operator’s reach.

2.8 Guard rails and ladders

2.8.1 It is the Owners’ responsibility to provide permanent access arrangements and protection by means of Ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

2.8.2 Dutyholders should be aware that the hoops of a ladder alone may not be effective in safely arresting a fall without injury. Dutyholders are therefore advised to review their risk assessments and consider if additional fall protection is required or alternative means of access is to be supplied.

Where dutyholders choose to use fall arrest equipment inside a hooped ladder to arrest a fall, they should be aware that hoops may interfere with the operation of some types of fall arrest equipment (for example, inertia reel devices). Dutyholders should contact their manufacturer or supplier for advice on the performance of such equipment when used in a hooped ladder.

Users of fall arrest equipment inside a caged ladder should also be aware of the possibility of injury from striking the cage following a fall. The use of climbing helmets to reduce the risk of injury may need to be considered (refer to HSE CCID 1-2012).

Where ladders are used as (or part of) an emergency escape route, they are to be fire resistant to comply with BS 476 part 7, 1989 or equivalent.

Ladders fixed and portable are to be suitable for use in the intended areas, and the Owner is to conduct risk assessments with regard to the use of wooden or aluminium ladders in an offshore drilling environment.

2.9 Fire and blast loading

2.9.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and/or temporary refuge. Where boundary bulkheads can be subjected to blast loading, the scantlings are to comply with *Pt 4, Ch 3, 4.16 Accidental loads* and *Pt 4, Ch 6, 9.1 General 9.1.6*.

Other Standards which will apply to fire and blast loading include:

API RP 2FB Recommended practice for design of offshore facilities against fire and blast loading.

■ *Section 3*
Drilling plant systems

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of the drilling plant equipment, systems, functional descriptions and operating philosophies are to be submitted for approval. Where considered necessary, risk assessments are also to be submitted for consideration.

3.1.2 The submitted information is to include the following as applicable to the equipment categories:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

Drilling equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of *Pt 3, Ch 7, 1 General*.

3.1.3 The generally recognised Codes and Standards frequently specified for drilling equipment are included in these Rules. These Codes and Standards may be used for certification but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

3.1.4 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility. Materials used in welded construction are to be of known and documented weldable quality.

3.1.5 For selection of acceptable materials suitable for hydrogen sulphide-contaminated products (sour service), reference is made to NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2Scontaining Environments in Oil and Gas Production, see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

3.1.6 Grey iron castings are not to be used for critical components.

3.1.7 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

3.1.8 In general, bolts and nuts are to comply with the Standards listed in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards*.

3.1.9 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2. Galvanising of high tensile bolts and nuts is to be avoided. Where non high tensile bolts and nuts are galvanised, they are to follow the guidelines of ASTM B695.

3.1.10 The risk of galvanic corrosion is also to be considered in the selection of all types of fasteners.

3.1.11 For general service, the specified tensile strength of bolting material is not to exceed 1000 N/mm^2.

3.1.12 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

3.1.13 All bolted structures are to have specific installation and tensioning design requirements made available to the Owner and LR for review before assembly.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming part of such systems are to be in accordance with an acceptable Code or Standard, *see Pt 3, Ch 7, 1.5 Recognised Codes and Standards*, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the drilling and well-testing installations are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the installation's main, auxiliary and/or essential services for drilling plant operations in suitable cases. Attention is drawn to the relevant Chapters of *Pt 5 MAIN AND AUXILIARY MACHINERY*, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 Piping for services essential to the drilling operations, and piping containing hydrocarbon or other hazardous fluids, is to be of steel or other approved metallic construction. Piping material for H_2S -contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2S-containing Environments in Oil and Gas Production, see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

3.2.4 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.5 In mud, cement or other systems where the piping is likely to be subjected to considerable erosion, a suitable erosion allowance is to be specified, and anticipated service conditions such as vibration, velocity, hydraulic hammer pressure pulsations are also to be taken into account.

3.2.6 The number of detachable pipe connections in the drilling piping systems is to be limited to those which are essential for mounting and dismantling. Non-critical auxiliary systems such as water and air service may be attached with approved detachable couplings.

3.2.7 Valves used for the shutting down and control of equipment in an emergency, such as choke manifolds and standpipe manifolds, are to be provided with indicators to show clearly whether they are open or closed.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their Intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 All flexible hoses used during drilling operations are to be manufactured to a recognised Code or Standard and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate Standard. Transfer, mud, hydraulic and pneumatic hoses which may be liable to heavy external wear are to be specially protected. Protection against mechanical damage and from rushing/compression is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.3.4 Kill, choke and jumper hoses are to meet the minimum requirements of API 16C and API RP53.

3.3.5 Hydraulic control hoses serving well completion units and blow out preventers are to meet the requirements of API Spec 16E and API RP53.

3.3.6 Flexible piping is to meet the requirements of API RP 17B/ISO 13628-11:2007 *Recommended Practice for Flexible Pipe*. Inspection and maintenance procedures of flexible lines are to meet with requirements of API RP 7L.

3.3.7 Fiberglass and plastic pipe are to meet the requirements of the following main Standards and where applicable other standards in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*:

API RP 15CLT. Recommended practice for composite lined steel tubular goods.

API Spec 15HR. Specification for high pressure fiberglass line pipe.

API Spec 15LE. Specification for polyethylene line pipe (pe).

API Spec 15LR. Specification for low pressure fiberglass line pipe.

3.4 Design and construction

3.4.1 The design strength of drilling equipment is to comply generally with LR agreed Codes and Standards.

3.4.2 Drilling equipment and systems are to be protected from excessive loads and pressures.

3.4.3 All drilling equipment is to be located in order to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

3.4.4 The equipment is to be suitable for the design environmental conditions for the unit and the submitted design data for drilling equipment is to include all loading conditions, for each item, including the most unfavourable combination of loads, and any external loading conditions.

3.4.5 A dedicated area suitably sized and classified for well test equipment is to be provided. The area is to be suitably protected with bunding and drainage to prevent any oil spillage from spreading to other areas of the unit.

3.4.6 All areas that are intended to contain permanent or temporary equipment are to be designed with utilities such as electrical power, fresh water, compressed air, PA system, ESD, firewater and/or deluge system and communication system.

3.4.7 The drilling plant will be designed and constructed with regard to safe handling and storage of heavy equipment.

3.4.8 Suitable drilling plant control systems are to be provided; as a minimum, these are to display drilling data, audible and visual alarms, anti-collision systems status, necessary process and storage systems data and are to control the mechanical and electrical equipment and other necessary utilities for safe drilling operations.

3.4.9 The drilling plant is to be equipped with sufficient emergency stops in critical areas. Details of the drilling plant emergency alarm system are to be submitted to LR for review.

3.4.10 The drilling plant will be designed to reduce the potential of ignitions arising from static, lightning and stray currents.

3.5 Drilling equipment

3.5.1 All drilling equipment shall, as a minimum, meet the requirements of the following main Standards and where applicable other standards referenced in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

Consideration is to be given during the design and installation of all drilling equipment to reducing the risk to personnel during routine maintenance or operations:

API Spec 7-1 Specification for rotary drill stem elements.
API Spec 7K Specification for drilling and well servicing equipment.
API RP 7G Recommended practice for drill stem design and operating limits.
API Spec 8A Specification for drilling and production hoisting equipment.
API RP 8B Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment.
API Spec 9A Specification for wire rope.
API RP 9B Recommended practice on application, care and use of wire rope for oil-field service.
API Spec 7F Oil-field chain and sprockets.
API RP 7L Procedures for inspection, maintenance, repair, and remanufacture of drilling equipment.
API Spec 8A Specification for drilling and production hoisting equipment.
API RP 8B/ ISO 13534:2000 Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment.
API Spec 8C/ ISO 13535:2000 Specification for drilling and production hoisting equipment (psl 1 and psl 2).
API Spec 9A Specification for wire rope.

API RP 9B Recommended practice on application, care and use of wire rope for oil-field service.
API RP 13C/ ISO 13501 Recommended practice on drilling fluid processing systems evaluation.
API RP 2003 Protection against ignitions arising out of static, lightning and stray currents.
API RP 7HU1 Safe use of 2-Inch hammer unions for oilfield applications.

3.6 Drilling well control equipment

3.6.1 Drilling well control equipment, including auxiliary well control equipment, is to meet the requirements of the following main Standards and where applicable other standards referenced in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

3.6.2 Consideration during the design of the well control system to reducing the risk to personnel during routine maintenance or operations is to be undertaken.

3.6.3 Where surface BOPs are being used, a risk assessment on the need for an SID (sea bed isolation device) is to be submitted to LR for review.

3.6.4 The number of components and arrangement for the blow out preventer stack is to be presented to LR for review:

API Spec 16A/ ISO 13533:2001 Specification for drill-through equipment.
API Spec 16C Specification for choke and kill systems.
API RP 16D Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment.
API Spec 16F Specification for marine drilling riser equipment.
API RP 16Q Recommended practice for design, selection, operation and maintenance of marine drilling riser systems.
API Spec 16R Specification for marine drilling riser couplings.
API Spec 16RCD Specification for drill through equipment rotating control devices.
API RP 16ST Coiled tubing well control equipment systems.
API RP 53 Blowout prevention equipment systems for drilling wells.
API RP 59 Recommended practices for well control operations.
API RP 64 Recommended practices for diverter systems equipment and operations.

■ *Section 4*
Bulk storage wet and dry systems

4.1 General

4.1.1 The requirements for fired and unfired pressure vessels associated with the drilling plant and bulk storage vessels are to comply with the general requirements of *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

4.1.2 Pressure vessels are to comply with the design requirements in *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

4.1.3 Degasser and mud-gas separators are to be suitably constructed to handle the maximum design flow rate. All vented lines are to be of sufficient capacity and be vented to a safe location. Design particulars are to be submitted to LR for review.

4.1.4 Cementing units and associated high pressure pipes and manifolds are to be suitably designed and tested. If the cement unit is designed to be used as a kill unit, the components, specifications, capacities and power arrangements are to be supplied to LR for review.

4.1.5 The bulk system is to be designed to receive, store and deliver required volumes of bulk material to the mud and cementing system. Design capacities of the system are to be submitted for LR review.

4.1.6 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see Pt 3, Ch 3, 2.10 Watertight and weathertight integrity*.

4.1.7 All bulk tanks, wet and dry, are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2 Dry bulk systems

4.2.1 All dry bulk tanks are to be fitted with weight or volume indicators and a high level alarm. Provision for manual measurement is to also be made available.

4.2.2 The dry bulk vessels are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2.3 All dry bulk lines (including ventilation lines) are to be designed for minimum flow resistance, minimum possible length and as few bends as possible. Connection points for purge air will be installed at critical flow areas in the bulk lines. Vent line outlets are to be kept as far as possible from HVAC inlets and normally manned areas.

4.2.4 The bulk air supply will be designed with redundancy and is to incorporate bulk air dryers. The compressors are to be located as close to the bulk storage tanks as possible.

4.2.5 The design is to prevent inadvertent mixing of cement and other bulk material.

4.2.6 All dry bulk storage vessels are to be equipped with safety valves or bursting discs to prevent damage due to overpressure. Bursting discs may only be used for vessels located in open areas or, if fitted in conjunction with a relief line, the discharge must be led to an open area.

4.2.7 For dry bulk storage vessels in enclosed areas, testable full open safety valves which can be vented out of the area are to be used. The enclosed areas where bulk storage vessels are located are to be ventilated such that a build-up of pressure will not occur in the event of a break or leak in the air supply system.

4.3 Wet bulk systems

4.3.1 Wet bulk storage tanks are to be suitably constructed with regard to the design maximum mud weight capacity of the vessel. All tanks are to be suitably equipped with equipment for preventing settling of mud.

4.3.2 The system will incorporate transfer systems with dedicated redundancy of pumps and manifolds. Sufficient by-passes with necessary valves for the liquid bulk in each storage tank are required. The systems are to be designed to transfer the relevant liquid bulk of design-specified weight and capacity to the liquid bulk tanks.

4.3.3 The design is to prevent inadvertent mixing of base oil and brine liquids.

4.3.4 High pressure mud pumps are to be fitted with pulsation dampers and relief valves set at the maximum allowable pressure of the system.

4.3.5 The mud pump relief line from the safety valve is to be self-draining and be as direct as possible with no bends and be suitably secured. The relief line after the relief valve is to be the same pressure rating as the pressure line before the relief valve. Facilities for flushing the vent lines are to be incorporated.

4.4 Mud mixing and storage system

4.4.1 The mud mixing and storage system is to be designed with sufficient capacity and structural strength to perform all planned mud mixing and storage operations with minimum risk of spillage or release of dust or fumes.

4.4.2 The entire mixing and storage system is to be designed for safe material handling and protection for personnel and the environment.

4.5 Mud treatment system

4.5.1 The mud treatment system is to be designed to operate without any risk to personnel with regard to spillage or exposure to hazardous substances.

■ *Section 5*
Offshore safety and pollution

5.1 Standards

5.1.1 Dutyholders are to meet the requirements of the following main Standards and, where applicable, other standards referenced in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*, or equivalent, as a minimum to ensure adequate safety to personnel and the environment.

API Spec 14A/ ISO 10432:2004 Specification for subsurface safety valve equipment.

API RP 14B/ ISO 10417:2004 Recommended practice for design, installation, repair and operation of subsurface safety valve systems.

API RP 14C Recommended practice for analysis, design, installation and testing of basic surface safety systems on offshore production platforms.

API RP 14E Recommended practice for design and installation of offshore production platform piping systems.

API RP 14F Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations.

API RP 14FZ Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations.

API RP 14G Recommended practice for fire prevention and control on fixed open type offshore production platforms.

API RP 14J Recommended practice for design and hazards analysis for offshore production facilities.

API RP 49 Recommended practice for drilling and well servicing operations involving hydrogen sulfide.

API RP 54 Recommended practice for occupational safety and health for oil and gas well drilling and servicing operations.

API Std 2000 Venting atmospheric and low-pressure storage tanks.

API RP 76 Contractor safety management for oil and gas drilling and production operations.

API RP 75 Recommended practices for development of a safety and environmental management program for offshore operations and facilities.

■ *Section 6*
Competence

6.1 General

6.1.1 Dutyholders are to ensure all their personnel are suitably trained and assessed with regard to their competence in performing their routine work and also with regard to emergency drills and duties.

■ *Section 7*
Electrical installations

7.1 General

7.1.1 In general, electrical installations are to comply with the requirements of *Pt 6, Ch 2 Electrical Engineering*.

7.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with *Pt 7, Ch 2 Hazardous Areas and Ventilation* and *Pt 3, Ch 7, 9 Fire, hazardous areas and ventilation* or an equivalent standard acceptable to LR.

■ *Section 8*
Control systems

8.1 General

8.1.1 In general, control engineering systems are to comply with the requirements of *Pt 6, Ch 1 Control Engineering Systems* and/or with the appropriate Codes or Standards defined in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories* as applicable.

8.1.2 The control aspects of the blow out preventer stack are to be in accordance with the requirements of *Pt 3, Ch 7, 3.6 Drilling well control equipment*.

8.1.3 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of *Pt 7, Ch 1 Safety and Communication Systems*.

■ *Section 9*
Fire, hazardous areas and ventilation

9.1 General

9.1.1 Hazardous areas and ventilation are to comply with *Pt 3, Ch 3, 3 Hazardous areas and ventilation* and *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

9.1.2 The general requirements for fire safety are to comply with *Pt 7, Ch 3 Fire Safety*.

9.1.3 A general arrangement drawing(s) of the unit, showing hazardous zones and spaces as well as the design philosophy is to be submitted to LR for review. The drawing is to refer to the requirements of *Pt 7, Ch 2 Hazardous Areas and Ventilation* and equivalent standards, for example:

API RP 14F. Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations.

API RP 14FZ. Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations.

API RP 505. Recommended practice for classification of locations for electrical installations at petroleum facilities classified as class 1, zone 0, zone 1, and zone 2.

API RP 500. Recommended practice for classification of locations for electrical installation at petroleum facilities classified as class 1, division 1 and division 2.

IP Model code P15.

■ *Section 10*
Risks to personnel from dropped objects

10.1 Goal

10.1.1 The requirements of this Section are to ensure that risks to personnel from dropped objects, hereinafter referred to as DROPS, are continuously addressed, in so far as they affect the objectives of classification.

10.2 Class notation

10.2.1 Where the requirements of this Section are met to the satisfaction of LR, units will be eligible to be assigned the **DROPS** class notation. This notation will be retained as long as the preventive measures to protect personnel from hazards from dropped objects are found, upon examination at the prescribed surveys, to be maintained to the satisfaction of LR.

10.3 Scope

10.3.1 Each unit is required to have a DROPS management system in place and be relevant to the design and specifics of the unit.

10.3.2 The Builder or Owner will create a general arrangement drawing of critical DROPS areas which will be clearly displayed in general information areas throughout the unit and accommodation.

10.3.3 The DROPS GA drawing will identify each area with colour coding and will clearly indicate the criticality levels within areas of the unit. The colour criticality coding is to be assigned as follows:

(a) Green Zone:

Where the layout and activities of the area present little likelihood of personnel being exposed to potential dropped objects under normal circumstances.

(b) Yellow Zone:

Where the layout and activities of the area present some risk of personnel being exposed to potential dropped objects under normal circumstances.

(c) Red Zone:

Where the layout and activities of the area present significant risk of personnel being exposed to potential dropped objects under normal circumstances.

10.3.4 Zones are to be clearly displayed at all access points to the respective areas. All signs are to be pictorial to eliminate potential issues with different languages. Refer to BS EN IEC 62079:2001 Section 4.7.3.2 for further information.

10.3.5 All third party equipment, permanent or temporary, is to undergo a design risk assessment before installation. Records and methods of inspecting the third party equipment are to be maintained and available for LR review.

10.3.6 Suitable equipment and hand tools for working at height are to be provided. Details and records of inspection of such tools and equipment are to be maintained and available for LR review.

10.3.7 When the use of DROPS shelters are incorporated into the safety management system, full structural and installation details of the shelters, including the intended level of safety, are to be presented for LR review.

10.3.8 The preventive maintenance systems of the unit are to indicate where specialised work at height tooling is required for routine maintenance.

10.3.9 An inventory of permanent fixed equipment is to be created and maintained by the unit; the inventory is to include photographs and a description of each item. The photographs are to be taken from a distance and also from close up to avoid confusion with identification. Each individual item of equipment is to be identified by permanent marking or by the use of suitably attached durable labels.

10.3.10 An inventory of temporarily installed equipment is to be created and maintained by the unit. This will incorporate scheduled routine inspections to verify that no modifications, changes or damage to the equipment has occurred since the initial inspection on installation, or previous scheduled inspection.

10.3.11 A program of scheduled surveys and inspection will be created; methods and records of inspection and any remedial actions are to be maintained and available for LR review.

10.3.12 A record of failed items, with reason for failure, is to be maintained and is to be available for review by LR.

■ *Section 11* Trials

11.1 General

11.1.1 Before a new drilling plant (or any alteration or addition to an existing plant) is put into service, final drilling plant trials are to be carried out by an approved technical organisation, as defined in *Pt 3, Ch 7, 11.2 Approved technical organisation*, to demonstrate that the integral drilling plant is suitable for safe operation and can operate as per the design.

11.1.2 The operational philosophy of the drilling plant is to be submitted for consideration. The operational philosophy is to include:

(a) each task to be performed, e.g., drilling operations, equipment inspection/maintenance, cleaning and instrument observation;
(b) a robust identification of the hazards associated with each task;
(c) the methods used to manage the identified hazards.

11.1.3 Where the operational aspects of the drilling plant have an effect on the overall safety of the drilling unit, the personnel on board or the environment, these aspects are to be to the satisfaction of LR.

11.1.4 The final drilling plant trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on an approved test schedule. The test schedule is to be submitted to LR for approval.

11.2 Approved technical organisation

11.2.1 An approved technical organisation, for the purposes of this Section, is one that can demonstrate that the trials are witnessed by competent experienced personnel with a minimum of 10 years' offshore operational drilling plant experience. CVs are to be submitted to LR for review. The approved technical organisation is to be acceptable to the Owner and LR.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the process plant facility on board production and storage units as defined in *Pt 3, Ch 3 Production and Storage Units*. The process plant facility includes the equipment and supporting structure and systems used for oil and gas production including separation, treating and processing systems and equipment and systems used in support of production operations, where permitted by the national Flag Administration. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the design strength and safety aspects of the process plant facility installed on board production and storage units.

1.1.3 The operational aspects and reliability of the production and process plant facility are not covered by class except when they have an effect on the overall safety of the production unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that a unit with an installed production and process plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the production and process plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit’s Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 Production units with an installed process plant facility which comply with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **PPF**.

1.2.3 When a production unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.3 Scope

1.3.1 The following additional topics applicable to the special features class notation are covered by this Chapter:

- Major equipment and structures of the production and process plant.

- Oil or gas processing system, including flowlines from the riser termination flanges, manifolds, production swivels, separators, heaters and coolers, relief and blowdown systems and water treatment systems.
- Production plant safety systems.
- Production plant utility systems.
- Riser compensating and tensioning system.
- Relief and flare system.
- Well control system.

1.3.2 Unless agreed otherwise with LR the Rules consider the following as the main boundaries of the production and process plant facility:

- Any part of the production and process system located on the unit including the riser connecter valve or christmas tree but excluding the risers is considered part of the facility.
- The shut-down valve at the export outlet from the production or process plant to the storage or offloading facility.
- The outlet from hydrocarbon flare and vent system.

1.4 Plant design characteristics

1.4.1 The design and arrangements of the process plant are to comply with the requirements of this Chapter and with recognised Codes and Standards, *see Pt 3, Ch 8, 1.5 Recognised Codes and Standards*.

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administration in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes or Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in *Pt 3, Ch 8, 1.4 Plant design characteristics 1.4.4*, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any possible combination of the following loads, as applicable:

(a) Static and dynamic loads due to wave-induced motions of the unit.
(b) Loads resulting from hull flexural effects at the plant support points, as appropriate.
(c) Direct wind loads.
(d) Normal gravity and functional loads.
(e) Thermal loads, as appropriate.
(f) Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised and tension-leg units:

  25° in any direction.
- Surface type units:

  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:

  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in *Pt 3, Ch 8, 1.4 Plant design characteristics 1.4.4*, the plant is to be assumed to have maximum operating weights, temperatures and pressures unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

1.5 Recognised Codes and Standards

1.5.1 Installed process plant facility designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage in order that a basis for acceptance of the standards may be agreed. *See Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories* for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the production and process plant as defined in Appendix A. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of production and process plant equipment are to be based on equipment categories agreed with LR.

1.6.2 Production and process plant equipment including its associated pipes and valves is to be divided into equipment Categories **1A**, **1B** and **II**, depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

II Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. A full list of equipment categories for each production and process plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A**

- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B**

- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) **Category II**

- Supplier's/manufacturer's works' certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the production and process plant facility is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:

- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.9 Installation of plant equipment

1.9.1 The installation of equipment on board the unit is to be controlled by LR in accordance with the following principles:

- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category **II** equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.10 Maintenance and repair

1.10.1 It is the Owner's/Operator's responsibility to ensure that installed production and process plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specification.

1.10.2 When it is necessary to repair or replace installed production and process plant, any repaired or spare part is to be subject to the equivalent certification as the original.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2* Structure

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:

- General arrangement plans of the plant layout.
- Plans and design calculations as required for derricks in *Pt 3, Ch 7, 2 Structure*, when appropriate.
- Structural plans of equipment skids and design calculations.
- Structural plans of equipment support frames and trusses and design calculations.
- Flare structures and design calculations.

2.2 Materials

2.2.1 Materials are to comply with *Pt 3, Ch 1, 4 Materials* and material grades are to comply with *Pt 4, Ch 2 Materials* using the categories defined in this Section.

2.2.2 Support structures for the production and process plant are to be divided into the following categories:

- Primary structure.
- Secondary structure.

2.2.3 Some specific examples of structural elements which are considered as primary structure are as follows:

- Module main frame members and deck support stools.
- Main legs and chords including end connections.
- Foundation bolts.

2.3 Miscellaneous structures

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support frames and trusses, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. The design requirements of *Pt 3, Ch 8, 1.4 Plant design characteristics* are to be complied with.

2.3.2 The design of process plant support structures should integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the production and process plant are to be in accordance with *Pt 3, Ch 3, 2 Structure* and *Pt 4, Ch 5, 2 Permissible stresses*.

2.4 Flare structures

2.4.1 Flare structures are to be designed for an emergency condition and for normal operating conditions as defined in *Pt 3, Ch 8, 1.4 Plant design characteristics* and in accordance with an appropriate Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.4.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.4.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in *Pt 3, Ch 8, 1.4 Plant design characteristics*.

2.4.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see Pt 4, Ch 5 Primary Hull Strength*.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.4.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.4.7 Wind loads are to be calculated in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code) or a recognised Code or Standard, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.4.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

2.5 Lifting appliances

2.5.1 Lifting appliances used for handling flare structures and blow out preventers are to be in accordance with LR's LAME Code, *see also Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

2.6 Guard rails and ladders

2.6.1 It is the Owners' responsibility to provide permanent access arrangements and protection by means of ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

Section 3
Production, process and utility systems

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of production, process and utility systems and equipment listed in *Pt 3, Ch 8, 1.3 Scope*, and diagrammatic plans of the associated piping systems, are to be submitted for approval.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming parts of such systems are to be in accordance with a recognised Code or Standard, *see Pt 3, Ch 8, 1.5 Recognised Codes and Standards*, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the production and process plant are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the unit's main, auxiliary and/or essential services for process plant operations in suitable cases. Attention is drawn to the relevant Chapters of *Pt 5 MAIN AND AUXILIARY MACHINERY*, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.4 The number of detachable pipe connections in hydrocarbon production and process piping is to be limited to those which are necessary for installation and dismantling. The pipe connections are to be suitable for the intended use.

3.2.5 Soft-seated valves and fittings which incorporate elastomeric sealing materials installed in systems containing hydrocarbons or other flammable fluids are to be of a fire-tested type.

3.2.6 The production and process system piping is to be protected from the effects of fire, mechanical damage, erosion and corrosion. Corrosion coupons or test spool pieces are to be designed into the system. Spool pieces are to be fitted in such a manner as to be easily removed or replaced. Sand probes and filters should be provided where necessary for extraction of sand or reservoir fracture particles.

3.2.7 The corrosion allowance for hydrocarbon production and process piping of carbon steel is not to be less than 2 mm.

3.2.8 Piping for services essential to the production and process operations, and piping containing hydrocarbon or other hazardous fluids is to be of steel or other approved metallic construction. Piping material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in H_2S - containing Environments in Oil and Gas Production, see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

3.2.9 Arrangements are to be made to isolate the unit from the supply and discharge of produced oil and gas by the provision of suitable shut-down valves on the unit and at the receiving installation. The valves on board the unit are to be operable from the control stations as well as locally at the valve.

3.2.10 If a single failure in the supply from utility systems such as compressed air or cooling water which are essential to the operation of the production and process plant could cause an unacceptable operating condition to arise, an alternative source of supply is to be provided.

3.2.11 Process vessel washout connections are to be fitted with non-return valves in addition to the shut-off valves.

3.2.12 The locking open/closed of valves is to be by means of a suitable keyed locking device operated under a permit-to-work system.

3.2.13 For process vessels which periodically require isolation prior to gas-freeing and personnel entry, pipelines which connect the vessel to a source of pressure and/or hazardous fluid are to be provided with isolating valves, bleed arrangements and means to blank off the open end of the pipe. For systems containing significant hazards, consideration is to be given to double block and bleed valves and blanking-off arrangements.

3.2.14 For ship units and other surface type units, the design of piping systems should take into consideration the effect of hull girder bending.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 Short lengths of flexible hose may be utilised to allow for limited misalignment or relative movement. All flexible hoses are to be manufactured to a recognised Code or Standard, and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate standard. Protection against mechanical damage is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.4 Christmas tree

3.4.1 The christmas tree is to have at least one remotely-operated, self-closing master valve and a corresponding wing valve for each penetration of the tree. In addition, there is to be a closing device for each penetration at a level higher than the wing outlets.

3.4.2 Additional wing outlets such as injection lines are to penetrate the christmas tree above the lowest remotely-operated master valve, and be fitted with a remotely-operated, self-closing control valve and a check valve installed as close as possible to the injection point. The injection point for hydrate inhibitor may be fitted below the lowest self-closing master valve if the christmas tree is fitted with valve(s) below this point.

3.4.3 All valves in the vertical penetrations of the christmas tree are to be capable of being opened and kept in the open position by means of an external operational facility independent of the primary actuator.

3.4.4 Valves that are important in connection with the emergency shut-down system such as the master and wing valves are to be fitted locally with visual position indicators.

3.4.5 Where exposure to H_2S -contaminated products is likely, materials and welds shall meet the requirements of the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in* H_2S *-containing Environments in Oil and Gas Production*.

3.5 Protective pressure relief

3.5.1 Process vessels, equipment and piping are to be provided with pressure-relieving devices to protect against system pressures exceeding the maximum allowable pressure such that the system will remain safe under all foreseeable conditions, unless the system is designed to withstand the maximum pressure which can be exerted on it under any circumstances. Where appropriate, sections of the production and process system are to be protected against underpressure resulting from a change of temperature or state of the contents, *see also Pt 3, Ch 8, 4.9 Protective and pressure relief devices*.

3.5.2 The pressure-relieving devices are to be sized to handle the expected maximum relieving rates due to any single failure or fire incident. The rated discharge capacity of any pressure-relieving device is to take into account the back pressure in the vent system.

3.5.3 For protected items or sections of the system not in continuous service, a single pressure-relieving device is acceptable. Block valves for maintenance purposes, where fitted, in the pressure relief lines are to be interlocked with the source of pressure or spare relief valves as applicable.

3.5.4 For any particular item or section of the system in continuous service at least two pressure relief possibilities are to be provided for operational and maintenance purposes. In this case, each pressure relief possibility is to be designed to handle 100 per cent of the maximum relieving rate expected unless alternative systems are available or short-term shutdown is acceptable.

3.5.5 If more than two pressure relief possibilities are provided on any particular item or section of the system in continuous service, and any pressure relief possibility is designed to handle less than 100 per cent of the maximum relieving rate expected, the arrangements are to be such as to allow any one device to be isolated for operational and maintenance purposes without reducing the capacity of the remaining devices below 100 per cent of the maximum relieving rate.

3.5.6 Block valves fitted in pressure relief lines for isolation purposes are to be of the full-flow type, capable of being locked in the fully open position by an approved keyed method.

3.5.7 The arrangement in *Pt 3, Ch 8, 3.5 Protective pressure relief 3.5.4* or *Pt 3, Ch 8, 3.5 Protective pressure relief 3.5.5* is to ensure that all relief possibilities cannot be isolated from the system at the same time, by interlocking the block valves using an approved keyed method of interlocking operated under a permit-to-work system.

3.5.8 The set pressure for all pressure-relieving devices should generally not exceed the design pressure of the protected system or item. Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 110 per cent of the design pressure.

3.5.9 Bursting discs fitted in place of, or in series with, a pressure relief valve are to be rated to rupture at a pressure not exceeding the design pressure of the protected system or item. However, in the case of a bursting disc fitted in parallel with a relief valve(s), such as in vessels containing substances which may render a pressure relief valve inoperative or where rapid rates of pressure rise may be encountered, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at the operating temperature.

3.5.10 Pressure-relieving devices are normally to be connected to the flare and relief header to minimise the escape of hydrocarbon fluids, and to ensure their safe collection and disposal. Where appropriate, vent and discharge piping arrangements are to be such as to avoid the possibility of a hazardous reaction between any of the fluids involved.

3.5.11 In circumstances where hazardous vapours are released directly to the atmosphere, the outlets are to be arranged to vent to a safe location where personnel would not be endangered.

3.5.12 The inlet piping to a pressure relief device should be sized so that the pressure drop from the protected item to the pressure relief device inlet flange does not exceed three per cent of the device set pressure.

3.5.13 Pressure-relieving devices and all associated inlet and discharge piping are to be self-draining. Open vents are to be protected against ingress of rain or foreign bodies.

3.5.14 Relief piping supports are to be designed to ensure that reaction forces during relief are not transmitted to the vessel or system, and to ensure that relief devices are not used as pipe supports or anchors where the resultant forces could interfere with the proper operation of the device.

3.5.15 The design and material selection of the pressure-relieving devices and associated piping is to take into consideration the resulting low temperature, vibration and noise when gas expands in the system.

3.5.16 Positive displacement pumps and compressors for hydrocarbon oil/gas service are to be provided with relief valves in closed circuit, set to operate at a pressure not exceeding the maximum allowable pressure of the pump or equipment connected to it, and adequately sized to ensure that the pump output can be relieved without exceeding the system's maximum allowable pressure. Proposed alternatives to relief valves may be considered and full details should be submitted.

3.5.17 Relief valves may also be required on the suction side of pumps and compressors when recycling from the discharge side is possible.

3.6 Flaring arrangements

3.6.1 Facilities for gas flaring and oil burning are to be adequate for the flaring requirements during well control, well testing and production operations. For well testing, at least two flare lines are to be arranged through which any flow from the well may be directed to different sides of the unit.

3.6.2 The flare system is to be designed to ensure a clean, continuous flame. Provision is to be made for the injection of make-up gas into the vent system to maintain steady flaring conditions. A means of cooling the flare burners when used for well testing is to be available.

3.6.3 The flare burners are to be located at a safe distance from the unit. This distance, or protection zone, is to be determined by consideration of the calculated thermal radiation levels. For limiting thermal radiation levels, *see Pt 3, Ch 8, 3.9 Radiation levels*.

3.6.4 For well test systems, any flare line or other line downstream of the choke manifold is to have an inside diameter not less than the inside diameter of the largest line in the choke manifold.

3.6.5 Production and process plant venting systems are to be led to a liquid separator or knock-out drum to remove any entrained liquids which cannot be safely handled by the flare. Where a liquid blowdown system is provided, adequate provision is to be made in the design for the effects of back pressure in the system, and for vapour flash-off when the pressures in the blowdown system are reduced.

3.6.6 The flare system is to be capable of controlling any excess gas pressures resulting from emergency depressurising conditions.

3.7 Depressurising system

3.7.1 All production and process plant in which significant volumes of hydrocarbon liquids and gases with potential for incident escalation can be blocked in during a fire is to be capable of being depressurised. The capacity of the system should be based on evaluation of:

- system response time;
- heat input from defined accident scenarios;
- material properties and material utilisation ratio;
- other protection measures, e.g., active and passive fire protection;
- system integrity requirements.

3.7.2 The emergency depressurising system is to be designed to reduce pressures to a level to prevent rupture of the pressure-containing components. As a minimum requirement, the depressurising system is to be designed to ensure that the pressure is reduced to half the equipment's maximum allowable working pressure or 6.9 bar, whichever is lower, within approximately 15 minutes.

3.7.3 The cooling effect due to throttling of large volumes of high pressure gas in the discharge piping and valves during the depressurising period is to be evaluated for appropriate material selection. Where temperatures below minus 29°C are expected, the piping and valve material is to have specified average Charpy V-notch impact values of 27J minimum at the calculated lowest operational temperature.

3.7.4 The vent system design should ensure that allowance has been given to the possibility of high dynamic forces at pipe bends and supports during emergency depressurisation.

3.8 Cold vents

3.8.1 A cold vent is acceptable only if it is determined that the gas release will not create any danger to the unit. Due consideration should be given to the prevailing wind to ensure that gases do not flow down around operating areas. Where cold venting is provided, the arrangement is to minimise:

- Accumulation of toxic and flammable gases.
- Ignition of vent gases from outside sources.
- Flashback upon accidental ignition of the vent gases.

3.8.2 In order to avoid continuous burning of the vent gases in the case of accidental ignition, an extinguishing system using a suitable inert gas is to be installed.

3.8.3 The dew point of the gases is to be such that they will not condense at the minimum ambient temperature. In the case of liquid condensation in the cold vent piping, a drain or liquid collection system is to be provided to prevent accumulation of liquid in the vent line.

3.9 Radiation levels

3.9.1 The location and designed throughput of the flare is to take into consideration the levels of thermal radiation to ensure that exposure of personnel, structure and equipment is acceptable even under unfavourable wind conditions.

3.9.2 Under normal operating circumstances, the intensity of thermal radiation, including solar radiation, in unprotected areas where personnel may be continuously exposed is not to exceed 1,9 kW/m_2 in calm conditions. Allowance for the cooling effect of wind in unsheltered areas may be taken into consideration in determining the radiation levels.

3.9.3 Under emergency flaring conditions, the intensity of thermal radiation at muster stations and in areas where emergency actions of short duration may be required by personnel is not to exceed 4,7 kW/m_2 in calm conditions.

3.9.4 Suitable radiation screens, water screening or equivalent provision should be utilised to protect personnel, structure and equipment as necessary.

3.10 Firing arrangements for steam boilers, fired pressure vessels, heaters, etc.

3.10.1 The requirements of this Section are applicable to all types of fired equipment associated with the process plant. The equipment is to be constructed, installed and tested to the Surveyor's satisfaction.

3.10.2 Details of the design and construction of the fuel gas burning equipment for steam boilers, oil and gas heater furnaces, etc., are to be in accordance with agreed Codes, Standards and specifications normally used for similar plants in land installations,

suitably modified and/or adapted for the marine environment. Ignition of the burners is to be by means of permanently installed igniters, or properly located and interlocked pilot burners and main burners arranged for sequential ignition.

3.10.3 Proposals to burn gas or gas/air mixtures having relative densities compared with air at the same temperature greater than one will be specially considered in each case. *See also Pt 5, Ch 16 Gas and Crude Oil Burning Systems*.

3.10.4 Proposals for the furnace purging arrangements prior to ignition of the burners are to be submitted. Such arrangements are to ensure that any accidental leakage of product liquid or gas into the furnace, from a liquid or gas heating element, or from the accidental ingestion of flammable gases and/or vapours, does not result in hazardous conditions.

3.10.5 Compartments containing fired pressure vessels, heaters, etc., for heating or processing hazardous substances are to be arranged so that the compartment in which the fired equipment is installed is maintained at a higher pressure than the combustion chamber of the equipment. For this purpose, induced draft fans or a closed system of forced draught may be employed. Alternatively, the fired equipment may be enclosed in a pressurised air casing.

3.10.6 The fired equipment is to be suitably lagged. The clearance spaces between the fired equipment and any tanks containing oil are to be not less than 760 mm. The compartments in which the fired equipment is installed are to be provided with an efficient ventilating system.

3.10.7 Smoke box and header box doors of fired equipment are to be well fitted and shielded, and the uptake joints made gastight. Where it is proposed to install dampers in the uptake gas passages of fired equipment, the details are to be submitted. Dampers are to be provided with a suitable device whereby they may be securely locked in the fully open position.

3.10.8 Each item of fired equipment is to have a separate uptake to the top of the stack casing. Where it is proposed to install process fired equipment with separately fixed furnaces converging into a convection section common to two or more furnaces and/or a secondary radiant section at the confluence of the fired furnace uptake to the convection section, the proposed arrangements, together with the details of the furnace purging and combustion controls, are to be submitted.

3.11 Drain Systems

3.11.1 Drainage systems are to be provided to collect and direct drained or escaped liquids to a location where they can be safely handled or stored. In general, equipment is to be provided with a hard-piped, closed drainage system for small quantities of produced liquids, an open system handling drainage from hazardous areas, and an open system handling drainage from non-hazardous areas. These systems are to be entirely separate and distinct.

3.11.2 The hazardous drainage systems are to be kept separate and distinct from those of the main and auxiliary machinery systems. Consideration will be given to directing the process facilities hazardous drains to the facilities oil storage tanks. The hazardous drains fluids should not be allowed to free-fall into the tank. In units equipped with an inert gas system, a U-seal of adequate height, or equivalent method, should be arranged in the piping leading to the oil storage tanks.

3.11.3 Provision is to be made for protection against overpressurisation of a lower pressure drainage system when connected to a higher pressure system.

3.12 Bilge and effluent arrangements

3.12.1 Where, during operation, the production plant spaces contain, or are likely to contain, hazardous and/or toxic substances, they are to be kept separate and distinct from the unit's main bilge pumping system. This does not, however, preclude the use of the unit's main bilge system when the production plant is shut down, gas freed or otherwise made safe.

3.12.2 The bilge and effluent pumping systems handling hazardous and/or toxic substances should, wherever possible, be installed in the space associated with the particular hazard. Spaces containing pumping systems that take their suctions from a hazardous space will also be designated as hazardous spaces unless all associated pipelines are of all-welded construction without flanges, valve glands and bolted connections, and the pump is totally enclosed.

3.12.3 Bilge and effluent piping systems related to the production plant are to be constructed of materials suitable for the substances handled, including any accidental admixture of such substances.

3.12.4 Arrangements are to be provided for the control of the bilge and effluent pumping systems installed in production and process plant spaces from within the spaces and from a position outside the spaces.

■ *Section 4*
Pressure vessels and bulk storage

4.1 General

4.1.1 The Rules in this Section are applicable to fired and unfired pressure vessels associated with process plant, and drilling plant defined in *Pt 3, Ch 7 Drilling Plant Facility*.

4.1.2 Pressure vessels are to be designed in accordance with *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* and *Pt 5, Ch 11 Other Pressure Vessels* or with internationally recognised and agreed Codes and Standards and in accordance with the requirements of *Pt 3, Ch 8, 1 General*.

4.1.3 The list in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards 1.2.10* gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification but the additional requirements given in the Rules apply and the Rules will take precedence over the Codes and Standards wherever conflict occurs.

4.1.4 Portable gas cylinders and other pressure vessels used to transport liquids or gases under pressure are to comply with an acceptable National or International Standard.

4.1.5 Where pressure parts are of such an irregular shape that it is impracticable to design their scantlings by the application of recognised formulae, the acceptability of their construction is to be determined by hydraulic proof testing and strain gauging or by an agreed alternative method.

4.2 Plans and data submissions

4.2.1 Design documentation is to be submitted for all pressure vessels.

4.2.2 The submitted information is to include the following:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations for normal operating and emergency conditions.
- Bill of Materials including material specifications as necessary.
- Fabrication specifications including welding, heat treatment, type and extent of NDE.

4.3 Equipment certification

4.3.1 Equipment certification is to be carried out in accordance with *Pt 3, Ch 8, 1 General* and equipment categories are to comply with *Pt 3, Ch 17, 2.3 Production equipment 2.3.1* in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

4.4 Materials

4.4.1 Materials for pressure vessels are to comply with *Pt 3, Ch 1, 4 Materials* and the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), except where modified by this Section.

4.4.2 Welded carbon/manganese (C–Mn) steels used for major pressure containing parts should have a chemical composition limited by the carbon content and the carbon equivalent:

Carbon content $C \leq 0{,}25$

When the elements in the following formula are known, this formula is to be used:

Carbon Equivalent:

$$\mathrm{CE} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15} \leq 0{,}45$$

Symbols are as defined in the Rules for Materials.

4.4.3 The use of material not meeting these limitations is subject to special consideration in each case. The welding of such materials normally requires more stringent fabrication procedures regarding the selection of consumables, preheating and post weld heat treatment.

4.4.4 Materials for pressure containing parts are to be tested at the temperature specified in *Ch 13, 4.2 Cutting and forming of shells and heads 4.2.5* in *Ch 13 Requirements for Welded Construction* of the Rules for Materials and shall achieve a minimum energy of 27J for materials with specified minimum yield strength less than or equal to 360 MPa and 42J for higher strength materials.

4.4.5 Equipment and components required for hydrogen sulphide sour service shall meet the property requirements of NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in* H_2S *-containing Environments in Oil and Gas Production*.

4.4.6 Materials employed in liquefied natural gas pressure vessels are to be impact tested in accordance with *Pt 4, Ch 2 Materials*.

4.5 Design pressure and temperature

4.5.1 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of the safety valve. If the design of the system is such that it may be possible for it to see a vacuum, the design pressure shall also consider the minimum working pressure which the system may see.

4.5.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operating conditions.

4.5.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

4.5.4 The design temperature, *T*, used to evaluate the allowable stress, $\boldsymbol{\sigma}$, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when the plans of the pressure part are being considered. For fired steam boilers, *T* is to be taken as not less than 250°C.

4.6 Design safety factors

4.6.1 The term 'allowable stress', $\boldsymbol{\sigma}$, is the stress to be used in the formulae for calculating the scantlings of pressure vessels.

4.6.2 The allowable stress used for the design of a pressure vessel is to be in accordance with the Code or Standard being used to design that vessel.

4.6.3 Pressure vessels are to be designed for the emergency conditions referred to in *Pt 3, Ch 8, 1.4 Plant design characteristics*.

4.6.4 It is not permissible to use the allowable stress levels of one Code or Standard to determine the scantlings using the formulae from a different Code or Standard.

4.6.5 The yield strength used in the determination of allowable stress or in calculations is not to exceed 0,85 of the specified minimum tensile strength of the material in question.

4.7 Construction and testing

4.7.1 Fabrication documentation is to be compiled by the manufacturer simultaneously with the fabrication in a systematic and traceable manner so that all the information regarding the design specification, materials, fabrication processes, inspection, heat treatment, etc., can be readily examined by the Surveyor.

4.7.2 Welding procedures and construction requirements for welding shall be in accordance with those specified in *Ch 12 Welding Qualifications* and *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

4.7.3 Procedures for performing non-destructive examination and the acceptance criteria to be applied shall be in accordance with *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

4.8 Hydrostatic test pressure

4.8.1 Pressure vessels are to be subject to a hydrostatic test in accordance with the applied Code, Standard, or specification before being taken into service.

4.8.2 The hydrostatic test pressure is to be a minimum of 1,5 x design pressure if not specified in the Code or Standard.

4.8.3 The pressure and holding time are to be recorded.

4.8.4 Primary general membrane stresses are in no case to exceed 90 per cent of the minimum yield strength of the material.

4.9 Protective and pressure relief devices

4.9.1 Pressure vessels are to be provided with protective devices so that they remain safe under all foreseeable conditions.

4.9.2 Where pumps and pressure surges are capable of developing pressures exceeding the design conditions of the system, effective means of protection such as pressure relief devices or equivalent are to be provided.

4.9.3 Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 121 per cent of the design pressure. For specific fire contingencies where accumulated pressure could exceed 121 per cent, design proposals will be specially considered.

4.9.4 Bursting discs fitted in place of or in series with safety valves are to be rated to burst at a maximum pressure not exceeding the design pressure of the vessel at the operating temperature. Bursting discs are only to be used for pressure vessels located in open areas or if fitted in conjunction with a relief line led to an open area.

4.9.5 Where a bursting disc is fitted downstream of a safety valve, the maximum bursting pressure is also to be compatible with the pressure rating of the discharge system.

4.9.6 In the case of bursting discs fitted in parallel with relief valves to protect a vessel against rapid increase of pressure, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at operating temperature.

4.9.7 Pressure relief devices are to be type tested to establish their discharge capacities at their maximum rated design pressures and temperatures in accordance with an approved Code or Standard.

4.9.8 Where pressure relief devices can be isolated from the pressure vessel whilst in service, there is to be an alternative independent pressure relief device. The system pressure relief valve set pressure and bursting disc rupture pressure should be displayed at the respective operating position.

4.9.9 Any isolating valves used in conjunction with pressure relief devices are to be the full flow type capable of being locked in the full open position. Where isolating valves are arranged downstream and upstream of a relief device they are to be interlocked with each other.

4.9.10 Where pressure relief devices are duplicated on the same vessel or system and fitted with isolating valves, these valves are to be so interlocked as to ensure that before one relief device is isolated the other relief device is fully open and the required discharge capacity is maintained. The interlocking system is to be submitted for approval.

4.9.11 The design of the pressure-relieving system is to take into account the characteristics of the fluid handled and any extreme environmental condition recorded for the geographical zone of operation. The vent and pressure relieving systems are to be self-draining.

4.9.12 The rated discharge capacity of any pressure relief device is to take into account the back pressure in the vent systems. Where hazardous vapours are discharged directly to the atmosphere, the outlets are to be arranged to vent to a safe location.

4.10 Bulk storage vessels

4.10.1 Bulk storage vessels are to be designed in accordance with the general requirements of this Section and with one of the internationally recognised Codes or Standards for fusion welded pressure vessels quoted in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards 1.2.10*, and in accordance with the design requirements given in *Pt 3, Ch 8, 1 General*, *see also Pt 3, Ch 7, 3 Drilling plant systems*

4.10.2 For bulk storage vessels in enclosed areas, testable safety valves are to be used, which can be vented out of the area. Such enclosed areas are to be ventilated so that a pressure build-up will not occur in the event of a break or a leak in the air supply system.

4.10.3 Bulk storage vessels are normally to be supported by suitable skirts in order to distribute the loads into the supporting structure.

4.10.4 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see Pt 3, Ch 3, 2.10 Watertight and weathertight integrity*.

■ Section 5
Mechanical equipment

5.1 General

5.1.1 The Rules in this Section are applicable to all types of mechanical equipment associated with the production and process plant, with the exception of pressure vessels which are dealt with in *Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

5.1.2 Mechanical equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of *Pt 3, Ch 8, 1 General*.

5.1.3 The list in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards* gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification, but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

5.1.4 Production and process plant equipment is to be suitable for the service intended and for the maximum loads, pressures, temperatures and environmental conditions to which the system may be subjected.

5.2 Plans and data submissions

5.2.1 Design documentation for mechanical equipment is to be submitted in accordance with the equipment categories and certification requirements defined in *Pt 3, Ch 8, 1 General*.

5.2.2 The submitted information should include the following, as applicable to the equipment categories:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

5.3 Equipment certification

5.3.1 Equipment categories and certification of production and process plant equipment are to be in accordance with the requirements of *Pt 3, Ch 8, 1 General*.

5.3.2 A general guide to specific equipment categories are given in *Pt 3, Ch 17, 2.3 Production equipment 2.3.1* in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

5.3.3 Hoisting and pipe handling equipment are to comply with *Pt 3, Ch 7, 6 Competence*.

5.3.4 Associated equipment such as engines, electric motors, generators, turbines, etc., are to comply with the applicable Sections of the Rules.

5.4 Materials

5.4.1 Materials are to comply with *Ch 1, 4 General requirements for manufacture* and the Rules for Materials, except where modified by this Section.

5.4.2 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility and materials to be welded shall be of weldable quality.

5.4.3 As a minimum, Charpy impact tests are required to be carried out at the minimum design temperature (MDT) and exhibit minimum impact energies of 34J for minimum specified yield strengths of up to 360 MPa and 40J for higher yield strengths. For equipment used in LNG applications, the impact test temperature and energy requirements are to be in accordance with *Pt 4, Ch 2 Materials*.

5.4.4 For selection of acceptable materials suitable for hydrogen sulphide contaminated products (sour service), reference is to be made to the ISO 15156/NACE Standard in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards 1.2.31*.

5.4.5 Grey iron castings are not to be used for critical components.

5.4.6 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

5.4.7 In general, bolts and nuts are to comply with the Standards listed in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards*.

5.4.8 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2.

5.4.9 For general service the specified tensile strength of bolting material should not exceed 1000 N/mm^2.

5.4.10 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

5.5 Design and construction

5.5.1 The design strength of production and process plant equipment is to comply generally with *Pt 5 MAIN AND AUXILIARY MACHINERY*, as applicable, and with LR agreed Codes and Standards.

5.5.2 All equipment included in this Section is to be suitable for the design environmental conditions for the unit.

5.5.3 Combustion equipment and combustion engines are not normally to be located in a hazardous area, unless the air space is pressurised to make the area non-hazardous in accordance with the following criteria:

- Pressurisation air is to be taken from a safe area.
- An alarm is to be fitted to indicate loss of air pressure.
- An air lock system with self-closing doors is to be fitted.
- The exhaust outlet is to be located in a non-hazardous area, and be fitted with spark arresters, *see Pt 3, Ch 8, 5.5 Design and construction 5.5.4*.
- The combustion air inlet is to be located in a non-hazardous area.
- Automatic shut-down is to be arranged to prevent overspeeding in the event of accidental ingestion of flammable gases or vapours.

5.5.4 Efficient spark arresters, of LR approved type, are to be fitted to the exhaust from all combustion equipment, except from exhaust gas turbines. Water cooled spark arresting equipment is to be fitted with means to give a warning in the event of failing cooling water supply.

5.5.5 Exhaust gases are to be discharged so that they will not cause inconvenience to personnel or a dangerous situation during helicopter operations.

5.5.6 The equipment and systems are to be designed, installed, and protected so as to be safe with regard to the risk of fire, explosions, leakages and accidents.

5.5.7 For any equipment using magnetic bearings, a system overview of magnetic bearing systems fitted to the equipment is to be submitted to LR for information. Any equipment which uses active magnetic bearings is to be supplied with a back-up system, such that in the event of a power failure of the active magnetic system the equipment can be brought to a safe condition. Details of the back-up system are to be submitted to LR for approval. If the back-up system has a finite life then the manufacturer is to advise LR and the Owner what the life of the back-up system is. The Owner is to ensure that the life of the back-up system is monitored, so that the equipment is not operated beyond the life of the back-up system.

■ *Section 6* Electrical installations

6.1 General

6.1.1 In general, electrical installations are to comply with the requirements of *Pt 6, Ch 2 Electrical Engineering*.

6.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

■ *Section 7* Control systems

7.1 General

7.1.1 In general, control engineering systems are to comply with the requirements of *Pt 6, Ch 1 Control Engineering Systems* and/or the appropriate Codes and Standards defined in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

7.1.2 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of *Pt 7, Ch 1 Safety and Communication Systems*.

■ *Section 8* Fire, hazardous areas and ventilation

8.1 General

8.1.1 Hazardous areas and ventilation are to comply with *Pt 3, Ch 3, 3 Hazardous areas and ventilation* and *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

8.1.2 The general requirements for fire safety are to comply with *Pt 7, Ch 3 Fire Safety*.

■ *Section 9* Riser systems

9.1 General

9.1.1 Production riser systems which comply with the requirements of *Pt 3, Ch 12 Riser Systems* will be eligible for the special features class notation **PRS**.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units with installed dynamic positioning systems, and are additional to those applicable in other Parts of these Rules.

1.1.2 A unit provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the Class Direct website.

1.1.3 Requirements, additional to these Rules, may be imposed by the National Authority with whom the unit is registered and/or by the administration within whose territorial jurisdiction it is intended to operate. Where national legislative requirements exist, compliance with such regulations is also necessary.

1.1.4 For the purpose of these Rules, dynamic positioning means the provision of a system with automatic and/or manual control capable of maintaining the heading and position of the unit during operation within specified limits and environmental conditions.

1.1.5 For the purpose of these Rules, the area of operation is the specified allowable position deviation from the desired set point, *see Pt 3, Ch 9, 1.3 Information and plans required to be submitted 1.3.2*.

1.2 Classification notations

1.2.1 Units complying with the requirements of this Chapter will be eligible for one of the following class notations, as defined in *Pt 1, Ch 2 Classification Regulations*:

DP(CM) *See Pt 3, Ch 9, 2 Class notation DP(CM)*.
DP(AM) *See Pt 3, Ch 9, 3 Class notation DP(AM)*.
DP(AA) *See Pt 3, Ch 9, 4 Class notation DP(AA)*.
DP(AAA) *See Pt 3, Ch 9, 5 Class notation DP(AAA)*.

1.2.2 The notations given in *Pt 3, Ch 9, 1.2 Classification notations 1.2.1* may be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a unit is capable of maintaining heading and position under a standard set of environmental conditions (North Sea), *see Pt 3, Ch 9, 6 Performance Capability Rating (PCR)*.

1.2.3 Additional descriptive notes may be entered in the Class Direct website, indicating the type of position reference system, control system, etc.

1.2.4 Where a **DP** notation is not requested, dynamic positioning systems are to comply with the requirements of *Pt 3, Ch 9, 2 Class notation DP(CM)*, as far as is practicable.

1.3 Information and plans required to be submitted

1.3.1 The following information and plans are to be submitted in triplicate. The Operation Manuals specified in *Pt 3, Ch 9, 1.3 Information and plans required to be submitted 1.3.8* are to be submitted in a single set.

1.3.2 Details of the limits of the area of operation and heading deviations, together with proposals for redundancy and segregation provided in the machinery, electrical installations and control systems, are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail or in the event of fire or flooding, *see also Pt 3, Ch 9, 1.3 Information and plans required to be submitted 1.3.6* and *Pt 3, Ch 9, 4 Class notation DP(AA)* and *Pt 3, Ch 9, 5 Class notation DP(AAA)*.

1.3.3 Where a common power source is utilised for thrusters, details of the total maximum load required for dynamic positioning are to be submitted.

1.3.4 Plans of the following, together with particulars of ratings in accordance with the relevant Parts of the Rules, are to be submitted for:

(a) Prime movers, gearing, shafting, propellers and thrust units.
(b) Machinery piping systems.
(c) Electrical installations.
(d) Pressure vessels for use with dynamic positioning system.

1.3.5 Plans of control, alarm and safety sytems, including the following, are to be submitted:

(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference systems, together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.
(f) Details of the control systems, e.g., control panels and consoles, including the location of the control stations.
(g) Test schedules (for both works' testing and sea trials) that are to include the methods of testing and the test facilities provided.

1.3.6 For assignment of a **DP(AA)** or **DP(AAA)** notation, a Failure Mode and Effects Analysis (FMEA) is to be submitted, demonstrating that adequate segregation and redundancy of the machinery, the electrical installation and the control systems have been achieved in order to maintain position in the event of equipment failure, *see Pt 3, Ch 9, 4 Class notation DP(AA)*, or fire or flooding, *see Pt 3, Ch 9, 5 Class notation DP(AAA)*. The FMEA is to take a formal and structured approach and is to be performed in accordance with an acceptable and relevant National or International Standard, e.g., IEC 60812.

1.3.7 Where the **DP** notation is to be supplemented with a Performance Capability Rating (PCR), *see Pt 3, Ch 9, 1.2 Classification notations 1.2.2*, the following information is to be submitted for assignment of a PCR:

(a) Lines plan.
(b) General arrangement.
(c) Details of thruster arrangement.
(d) Thruster powers and thrusts.

1.3.8 Details of the intended modes of operation are to be submitted. As a minimum these are to include:

(a) a description of all the intended operating modes;
(b) details of the system configuration required for each mode of operation. When applicable, this is to include the configuration needed to meet the FMEA requirements of *Pt 3, Ch 9, 1.3 Information and plans required to be submitted 1.3.6*; and
(c) the procedures which are to be followed in each operating mode during normal and abnormal conditions.

1.3.9 A set of the operation and maintenance manuals is to be placed and retained on board the unit.

■ *Section 2*
Class notation DP(CM)

2.1 General

2.1.1 The requirements for class notation **DP(CM)** are given in *Pt 7, Ch 4, 2 Class notation DP(CM)* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which are to be complied with where applicable.

■ *Section 3*
Class notation DP(AM)

3.1 Requirements

3.1.1 The requirements for class notation **DP(AM)** are given in *Pt 7, Ch 4, 3 Class notation DP(AM)* of the Rules for Ships, which are to be complied with where applicable.

3.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable.

3.1.3 A manually initiated emergency alarm, clearly distinguishable from all other alarms associated with the dynamic positioning system, is to be provided at the dynamic positioning control station to warn all relevant personnel in the event of a total loss of dynamic positioning capability. In this respect consideration is to be given to additional alarms being provided at locations such as the Master's accommodation and operational control stations.

■ *Section 4*
Class notation DP(AA)

4.1 Requirements

4.1.1 The requirements for class notation **DP(AA)** are given in *Pt 7, Ch 4, 4 Class notation DP(AA)* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 5*
Class notation DP(AAA)

5.1 Requirements

5.1.1 The requirements for class notation **DP(AAA)** are given in *Pt 7, Ch 4, 5 Class notation DP(AAA)* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 6*
Performance Capability Rating (PCR)

6.1 Requirements

6.1.1 The requirements for PCR are given in *Pt 7, Ch 4, 6 Performance Capability Rating (PCR)* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 7*
Testing

7.1 General

7.1.1 The requirements for testing are given in *Pt 7, Ch 4, 7 Testing* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter applies to offshore units with positional mooring systems. This has been abbreviated to PMS.

1.1.2 The requirements apply to the following categories of unit and mooring type:

- Ship units, column-stabilised units, offshore loading buoys and other similar type moored floating structures.
- Multi-leg mooring systems, either spread-moorings or single-point moorings.
- Catenary systems or taut-leg systems.

1.1.3 Other types of application will be specially considered.

1.1.4 The requirements of this Chapter are not applicable to the mooring tethers on tension-leg units. For the design requirements of tension-leg units, *see Pt 4, Ch 4 Structural Unit Types*.

1.1.5 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration of the coastal state(s) with territorial jurisdiction over the waters in which it is intended to operate.

1.1.6 When other codes or standards are proposed, gap analysis and risk assessments are to be provided by the Owner/designers to demonstrate the alternative codes or standards provide an equivalent level of safety to the requirements of this section. Acceptance of the alternative codes or standards will be subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.2.2 For the assignment of the character letter **T** to floating offshore installations at a fixed location with positional mooring systems, the requirements of this Chapter are to be complied with. Mobile offshore units provided with a positional mooring system which complies with the requirements of this Chapter will be eligible for the assignment of a special features class notation as follows:

PM (Positional mooring system), or

PMC (Positional mooring system for mooring in close proximity to other vessels or installations. This notation will apply in particular to any unit operating adjacent to a fixed installation, e.g., crane unit, accommodation unit, support unit, etc.).

1.2.3 The positional mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner or Operator and recorded in the Operations Manual.

1.2.4 Units fitted with a thruster-assisted positional mooring system, which complies with the requirements of *Pt 3, Ch 10, 4 Design aspects*, will be eligible for the assignment of one of the following special features class notations:

TA(1)
TA(2)
TA(3)

1.2.5 The numeral in parentheses after the thruster-assist notation **TA** in *Pt 3, Ch 10, 1.2 Class notations 1.2.4* defines the thruster allowance which may be permitted in the design of the positional mooring system and is determined by the capacity/ redundancy of the thrust/machinery installation, *see Pt 3, Ch 10, 4 Design aspects*, *Pt 3, Ch 10, 13 Thruster-assisted positional mooring* and *Pt 3, Ch 10, 14 Thruster-assist class notation requirements*.

1.3 Definitions

1.3.1 The definitions given in this Section are for Rule application only and will not necessarily be valid in any other context, *see also Pt 1, Ch 2, 2 Definitions, character of classification and class notations*

1.3.2 **Offshore Unit**. *See Pt 1, Ch 2, 2.1 General definitions 2.1.13* and for the definitions of specific types relevant to this section such as **Mobile offshore unit** *see Pt 1, Ch 2, 2.1 General definitions 2.1.10* and **Floating offshore installation** *see Pt 1, Ch 2, 2.1 General definitions 2.1.9*.

1.3.3 **Ship**. Floating structure such as shuttle tanker or loading/offloading tanker which is to be temporarily moored to an offshore unit.

1.3.4 **Positional mooring**. Station-keeping by means of multi-leg mooring system with or without thruster-assist. The positional mooring system will consist of the following components, as relevant:

(a) Anchor points:

- Drag embedment anchors.
- Anchor piles.
- Suction anchor piles.
- Gravity anchors.
- Plate anchors.

(b) Anchor lines.

(c) Anchor line fittings:

- Shackles.
- Connecting links/plates.
- Rope terminations.
- Clump weights.
- Anchor leg buoyancy elements.

(d) Fairleads/bending shoes.

(e) Chain or wire rope stoppers.

(f) Winches or windlasses.

Where applicable, the structural or mechanical connection of these items to the unit is also considered to be part of the positional mooring system.

1.3.5 **Thruster-assist**. The use of thrusters, inclusive of their associated equipment, to supplement the unit's positional mooring system.

1.3.6 **Catenary mooring**. A mooring system which derives its compliancy mainly from the catenary action of the anchor lines. Some additional resilience is provided by the characteristic axial elasticity of the anchor lines.

1.3.7 **Taut-leg mooring**. A mooring system based on light-weight anchor lines pre-tensioned to a taut configuration with no significant catenary shape at any unit offset, and applying vertical and horizontal loads at the anchor points. With this type of system, compliancy is derived from the inherent axial elastic stretch properties of the anchor line.

1.3.8 **Single-point mooring**. An offshore positional mooring system arrangement in which the offshore unit freely weathervanes about a geostationary structure, generally using an internal or external turret, single buoy or single tower, *see Pt 3, Ch 2, 1.2 Class notations*

1.3.9 **Spread mooring**. A multi-line mooring system designed to maintain an offshore unit on an approximately fixed heading.

1.4 Plans and data submission

1.4.1 The positional mooring system will be subject to review and approval. The following information and plans are to be submitted in an agreed electronic format, to cover the design review and class approval of the positional mooring system:

(a) Plans of the positional mooring system and associated equipment are to be submitted including the following, as applicable:

- General arrangement of offshore floating unit (including hull and topsides general arrangements).
- Layout and arrangement of deck mooring equipment and support structures.
- Structural arrangement of mooring equipment, support structure and attachment point to the main structure or hull of the Offshore Unit.
- Mooring layout.
- Field layout.
- Anchor lines and fittings assembly.
- Anchor points.
- Fairleads/bending shoes, including associated mechanism, articulation or stopper.
- Cable (i.e. mooring line, steel wire or fibre rope or chain) stoppers or connectors.
- Winches, windlasses or tensioners.
- Deck equipment used in support of the mooring line failure response plan.

(b) For thruster-assisted positional mooring systems, plans of the following together with particulars of ratings, in accordance with the relevant Parts of these Rules are to be submitted:

- Prime movers, gearing, shafting, propellers and thrust units,*see also Pt 5 MAIN AND AUXILIARY MACHINERY*.
- Machinery piping systems.
- Electrical installations.

(c) In addition, details of proposals for the redundancy provided in machinery, electrical installations and control systems are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail. Where a common power source is utilised for thrusters, details of the total maximum load required for thruster-assist are to be submitted.

(d) Plans of control, alarm and safety systems including the following are to be submitted:

- Functional block diagrams of the control system(s).
- Functional block diagrams of the position reference systems and environmental sensors.
- Details of electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
- Details of the monitoring functions of the controllers, sensors and reference system together with a description of the monitoring functions.
- List of equipment with identification of the manufacturer, type and model.
- Details of the overall alarm system linking the centralised control station, subsidiary control stations, relevant machinery spaces and operating areas.
- Details of control stations, e.g., control panels and consoles, including the location of the control stations.
- Factory and customer acceptance test schedules which are to include the methods of testing and the test facilities provided.

1.4.2 The following supporting plans, data, calculations or documents are to be submitted in an agreed electronic format:

(a) General:

- Mooring design premise or basis of design.
- Moored unit details (dimensions and main particulars).
- Corrosion protection strategy and/or corrosion rates.

(b) Specifications:

- Materials.
- Mooring line components, mooring equipment and fittings.
- Model testing.

(c) Data reports:

- Environmental criteria (covering extreme as well as ambient conditions and all applicable operating environmental limits) and in addition for floating offshore installations at a fixed location:
- Detailed specialist environmental reports.
- Sea bed conditions.
- Soil and soil conditions.

(d) Design reports and calculations:

- Hydrodynamic/motion analysis.
- Mooring analysis.
- Model test report with results
- Design load report.
- Anchor line components: strength and fatigue, including as applicable, detailed design at points of constraints (e.g. in and out of plane bending analysis, in the case of top chain connection).
- Anchor point: strength and fatigue.
- Anchor point holding capacity.
- Fatigue.
- Equipment/ancillaries including the associated equipment, stoppers and fairleads: strength and fatigue.
- Corrosion protection and/or corrosion allowance.

(e) Other information:

- In-service inspection programme.

and in addition for floating offshore installations at a fixed location:

- Installation procedures.
- Installation records for piles and anchors, *see also Pt 3, Ch 14, 5 Drag embedment anchors – General*.
- Plan and schedule for PMS Initial Installation Survey,
- Mooring line components datasheets, inclusive of LR certificate of manufacturing and testing.
- LR certificate of manufacturing and testing of Deck mooring equipment including those used in support of the mooring line failure response plan.
- PMS Initial Installation Survey records.

and in addition for mobile offshore units:

- Anchor point holding capacity.

1.4.3 An Operations Manual, as required by *Pt 3, Ch 1, 3 Operations manual*, is to be submitted and the manual is to contain all necessary information and instructions regarding positional mooring and, where relevant, thruster-assisted positional mooring. It would normally also contain descriptions of the following:

- Mooring systems.
- Laying the mooring system.
- Anchor pre-loading.
- Pre-tensioning anchor lines.
- Tension adjustment.
- Mooring line tensions/ offset/integrity monitoring.
- Winch/windlass performance.

- Winch/windlass operation.
- Procedure in event of failure or emergency.
- Procedure for operating thrusters.
- Fault-finding procedures for thruster-assist system.
- Maintenance procedures. *see also Pt 3, Ch 10, 1.4 Plans and data submission 1.4.4*.
- Mooring line failure or loss of station keeping capability failure response procedure.

1.4.4 A PMS Inspection, Maintenance and Repair Manual (PMS IMMR Manual) is to be submitted covering frequency or scheduling, procedures and techniques of such activities for each component, related equipment and support structures. Due consideration is be given to the Oil and Gas UK Mooring Integrity Guidance. Calibration and testing of monitoring equipment (position monitoring, line integrity monitoring etc.) and associated alarms are also to be addressed. The PMS IMMR Manual is to report pertinent inspection, fault or defect detection, efficiency or degradation measurement methods (and associated error margins or accuracy), ways of recording the results. Inspection records should aim at enabling tracking and trending of degradation processes. This Manual is to address all inspections required for Periodical Surveys.

■ *Section 2*
Survey

2.1 General requirements

2.1.1 Positional moorings, with or without thruster-assist, are to be inspected and tested during manufacture/construction and under working conditions on completion of the installation.

2.1.2 The scope of inspection and/or testing to be carried out at the manufacturer's works is to be agreed with Lloyd's Register (hereinafter referred to as LR) before the work is commenced.

2.1.3 The general requirements for Periodical Surveys, contained in *Pt 1, Ch 2 Classification Regulations* of the Rules, are to be complied with.

2.1.4 The planned survey program is to be reviewed and where necessary updated between each Survey to the satisfaction of the LR Surveyor. A copy of the planned survey program and updates as agreed with the LR Surveyor, as well as survey records, are to be kept for information.

2.1.5 The inspection and survey records should be used to track and trend the observed degradations or anomalies. A PMS condition track record logbook is to be used to that effect. This is to be updated between each inspection and a copy made available to LR at every Periodical Survey.

2.1.6 Damage, anomalies and modifications to the positional mooring system should be reported to LR. Unless the design ensures the Offshore Unit and its positional mooring system can withstand a line failure with adequate level of safety (i.e. tension, clearance and offsets still satisfying intact criteria even after one line failed and still satisfying the damaged criteria after failure of second line) the unit shall be considered damaged from the time of the failure.

■ *Section 3*
Environmental conditions

3.1 General

3.1.1 The Owner/Operator or designer is to specify the environmental criteria for which the unit is to be considered. The extreme environmental conditions applicable to the location, or operating areas are to be specified, together with all operating environmental limits. Detailed specialist environmental reports are to be submitted, with sufficient supporting information to demonstrate the validity of the limiting criteria, *see Pt 3, Ch 10, 3.3 Metocean data*.

NOTE: For information on typical industry requirements on specialist environmental reports, "ISO 19901-1, Specific Requirements for Offshore Structures - Part 1 Metocean design and operating considerations" may be consulted. The Class requirements remain those found in the Rules for Offshore Units, especially this section.

3.1.2 A comprehensive set of operating and extreme environmental limiting conditions is to be submitted. This is to cover the following cases, as applicable, and any other conditions relevant to the system under consideration:

- Extreme environmental conditions.
- Limiting environmental conditions in which the unit and/or ship may remain moored.
- Limiting environmental conditions in which the unit and/or ship's main operating functions may be carried out (e.g., production and/or transfer of product).
- Limiting environmental conditions in which the unit and/or ship may (re)connect.

3.2 Environmental factors

3.2.1 The following environmental factors are to be considered in the design of the positional mooring system:

- Water depth range, local bathymetry, tidal variations and storm surges.
- Wind, (including gust spectral characteristics and squall characteristics as applicable).
- Waves (both wind waves and swell) with characteristic heights, periods, spectra and associated parameters.

NOTE: Where applicable, concomitant multiple swell regimes with various frequency and directional characteristics need to be reported

- Current (inclusive of all components, as well as vertical profile).
- Relative angles between wind, wind driven waves and current (and where applicable swell or squall).
- Marine growth.
- Air and sea temperatures.
-

and in addition for floating offshore installations at a fixed location:

- Sea bed conditions.
- Soil conditions.

3.2.2 In certain locations the following factors may need to be considered in the design of the positional mooring system:

- Sea ice or icebergs.
- Seismic characteristics and events, such as earthquakes.
- Sea water density (especially in the vicinity of estuaries)
- Snow or ice accretion.

3.3 Metocean data

3.3.1 As part of the environmental data, the following metocean data will normally be required to be submitted:

- 100 (or 50 for mobile offshore units), 10 and 1-year return period values for wind-speed, significant wave height and current.
- Directional data for extreme values of wind, waves and current.
- Wave height/period joint frequency distribution (wave scatter diagram).
- Wave spectral parameters.
- Wind/wave/current angular separation data.
- Current speed and/or directional variation over the water depth.
- Long-term wave statistics by direction.
- Squall time series data where relevant.

3.3.2 Data from a calibrated hindcast model covering the service life of the Offshore Unit and providing for each sea state (usually described as 3 hours stationary sea conditions) the data as follows:

- wind sea significant wave height, direction, peak period(s) and other parameters;
- swell sea significant wave height, direction(s), peak period(s) and other parameters;
- wind speed and direction; and
- current speed and direction.

NOTE: The data set should also report spectral formulation and parameters, as necessary. Where applicable, concomitant multiple swell regimes with various frequency and directional characteristics need to be included.

3.4 Environmental parameters

3.4.1 **Water depth**. Minimum and maximum still water levels are to be determined, taking full account of the tidal range, sea bed subsidence, wind and pressure surge effects. For floating offshore installations at a fixed location, data is to be submitted to show the variation in water depth in way of the installation. This data is to be referenced to a consistent datum and is to include, where relevant, the water depth in way of each anchor or pile, gravity base or foundation, pipeline manifold, and in way of the radius swept by an attached ship. The likelihood of sand waves or variation in sea-bed re-settlement at the site shall be documented (*See also Pt 3, Ch 10, 3.4 Environmental parameters 3.4.10* on sea-bed re-settlement).

3.4.2 **Wind**. The one-hour wind speed, plus wind gust spectrum, will normally require to be applied in design. The following wind gust spectra formulations can be adopted for the time varying component:

- API RP 2A.
- NPD/ISO
- Other published spectra formulations may be accepted, *see Pt 3, Ch 17, 1.2 Recognised Codes and Standards 1.2.16* .

The site specific environmental data report shall indicate whether the site is subject or not to squalls. In areas where squalls are prevalent, a specialist report is to provide a representative set of squall time series data. The data should be based on a number of recorded events and extrapolation or scaling techniques are to be documented as well as confidence intervals. Environmental parameters (current and waves) associated with the design squall event (*see Pt 3, Ch 10, 3.3 Metocean data 3.3.1* and *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters*) are to be documented. The report shall address such aspects as directionality, typical development and travel speed. Scaling techniques should be documented and special attention should be paid to the determination of rising slope and decay time in proposed scaled design squall time histories.

3.4.3 **Waves**:

(a) A site specific specialist report on meteorology, atmospheric and oceanic conditions is required to provide sea state characteristics and data for the location of operation. The sea state characterisation and data is to differentiate, as applicable to the location, between: local wind waves, swell and their combination.

(b) Sea state characteristics are to include as a minimum, spectral formulation and associated parameters, significant and maximum wave heights with associated range of peak and zero up-crossing periods.

(c) The data should include contours of equal probability of occurrence of significant wave height and peak period. Appropriate method of developing such wave contours is to be used, see *Pt 3, Ch 17, 1.2 Recognised Codes and Standards 1.2.17*. The source data, any extrapolation technique and the detailed derivation of the contours shall be fully documented.

(d) For certain locations, the sea conditions may be governed by a combination of local wind-driven waves and remotely generated swell, the specialist report shall provide information on the joint occurrence of wind driven waves and swell. The angular separation between directions of propagation of these two components shall also be informed.

(e) Where the metocean specialist report states that sufficient and adequate wave height /period joint distribution data are not available for the location, the report shall highlight what data is missing to enable such contours to be derived, and indicate alternative source for the missing data. The specialist report shall also propose a conservative range of wave heights and periods combinations for the location and design under consideration.

3.4.4 **Current**. A specialist report should document current data including velocity and direction and their vertical variation through the water depth, taking into account all relevant components including the following:

- Tidal currents.
- Circulation currents.
- Wind driven current.
- Storm surge generated current.
- loop and eddy currents
- soliton currents.

3.4.5 **Marine growth**. A specialist report is to document the characteristic data on typical local marine growth, such as growth rate, thickness and mass density.

3.4.6 **Air and sea temperature**. A specialist report is to provide pertinent air and sea temperatures data to substantiate the minimum and maximum air and sea design temperatures criteria for the location of operation in accordance with *Pt 3, Ch 1, 4.4 Minimum design temperature*.

3.4.7 **Sea bed conditions**. For floating offshore installations at a fixed location, the sea bed conditions at the proposed locations of the anchor points and along the anchor line corridors are to be determined to provide data for the design of the anchoring system. Requirements for site investigation are contained in *Pt 3, Ch 14 Foundations*.

3.4.8 **Soil conditions**. For floating offshore installations at a fixed location, the soil conditions at the proposed locations of the anchor points are to be determined to provide data for the design of the anchoring system. Requirements for site investigation are contained in *Pt 3, Ch 14 Foundations*.

3.4.9 **Sea ice and icebergs**. A specialist report (taking into consideration the recommendations and guidance from ISO 19906 as applicable) is to indicate whether the offshore location is prone to sea ice conditions or icebergs drifting. In such areas and where subfreezing temperatures can prevail for a major portion of the year, causing the formation of sea-ice data should be collected to assess the feasibility and establish relevant design criteria.

The data should at least include:

- the seasonal distribution of sea ice,
- the distribution and probability of ice floes, pressure ridges and/or icebergs,
- the effect of ice-gouges on the seabed from icebergs or ice ridges,
- the type, thickness and representative features of sea ice,
- drift speed, direction, shape and mass of ice floes, pressure ridges and/or icebergs, and
- strength and other mechanical properties of the ice.

3.4.10 **Seismic**. For areas that are determined to be seismically active, a specialist report shall document the characteristic seismic activity of the region (for further requirements *see Pt 3, Ch 14, 1.9 Earthquake*). Potential for soil liquefaction or seabed resettlement need to be reported. In shallow water depths, like coastal areas, specialist report shall also consider the seismicity of surrounding regions and indicate whether these could cause tsunamis at the site.

3.4.11 **Sea water density and salinity**. A specialist report is to document the local water salinity and density variations, (especially in vicinity of estuaries) and their impact on current, corrosion rate etc.

3.4.12 **Snow or ice accretion**. A specialist report (taking into consideration the recommendations and guidance from ISO 19906 as applicable) is to indicate whether the offshore location is prone to snow or subfreezing temperatures during parts of the year and provide data to substantiate and estimate the extent to which snow can accumulate on the structures and topsides and of its possible effect on the structure.

■ *Section 4*
Design aspects

4.1 Design cases

4.1.1 The positional mooring system, with or without thruster-assist, is to be designed for the following:

(a) **Intact Case:**

- This case assumes all anchor lines to be effective. Thruster-assist from an approved system can be included, *see Pt 3, Ch 10, 4.2 Thruster-assist systems*.

(b) **Damaged Case:**

- This case involves the failure of a single component, i.e., failure of an anchor line or anchor point, or failure of a component in the case of thruster-assist.

  Note - a single failure in the thruster system could lead to stoppage of several, or all, of the thrusters. This generally encompasses all non-redundant equipment in the chain of control and power supply to the thruster system or equipment which ensures the good operation of the thruster system.

  Note - loss or flooding of a buoyancy element or clump weight on a mooring line could lead to loss of effective restoring capacity of the line (as well as lead to loss of clearance of the line with adjacent subsea structures).

(c) **Transient Case:**

- The transient case will not normally require to be investigated.
- A transient quasi-dynamic analysis can be used to investigate whether a transient dynamic case requires to be considered in the design. When the maximum line tension and offset from the quasi-dynamic transient case does not exceed the maximum tension and offset from the corresponding quasi-dynamic damaged case, full dynamic transient load case will not normally be required to be investigated.

4.1.2 Sensitivity analyses on proposed PMS design are to encompass the level of accuracy of proposed inspection techniques and procedures, tolerances and margins on component properties (inclusive over the service life), as well as installation tolerances. Upon consideration in the design of such variations, the design should still satisfy the requirements of this Chapter.

4.1.3 A load case considering the failure of any one line adjacent to the first failed line should be run to assess the consequence of such serial failure. The results of the analyses of the positional mooring system with two lines failed should indicate this abnormal configuration does not lead to progressive collapse or incidents of substantial consequences such as loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking. Mooring line failure response procedure should be referred to from the time one line fails.

The results (offsets, tensions, clearances, etc.) of the two lines failure analyses are to be reported and used to set up the mooring line failure response procedure for the unit.

Note The mooring line failure response procedures shall include root cause assessment, repair planning, mitigations to limit further damage, ensure safe control of the Offshore Unit after failure of one line and ensure preparedness for further line failure will not have substantial consequences.

4.1.4 The design shall consider at least three draughts or loading conditions (fully ballasted, fully loaded and one between to attempt capture the most onerous load condition).

4.2 Thruster-assist systems

4.2.1 Thrusters can be used to reduce the mean load on the mooring system, provide damping of low frequency surge motion, and/or control the heading of the unit, in order to limit the overall excursions. Thruster intervention allowances for supplementary thruster-assist notations are given in *Pt 3, Ch 10, 4.2 Thruster-assist systems 4.2.1*.

Table 10.4.1 Thruster allowance

Case	Thruster allowance		
	TA(1)	**TA(2)**	**TA(3)**
Operating (Intact)	None	70% of all thrusters	All thrusters
Survival (Intact)	70% of all thrusters	All thrusters	All thrusters
Operating (Single line failure)	None	70% of all thrusters	All thrusters
Survival (Single line failure)	70% of all thrusters	All thrusters	All thrusters

NOTES

1. The conditions for assignment of supplementary notations TA(1), TA(2) and TA(3) are defined in *Pt 3, Ch 10, 14 Thruster-assist class notation requirements*.

2. Net thrust values can be applied in the calculations, to the extent indicated in the Table. The basis for deductions due to thruster-hull, thruster-current and thruster-thruster interference is to be documented and included in the design submission.

3. Refer to *Pt 3, Ch 10, 4.1 Design cases 4.1.1* for the Rule basis of failure, including thruster system failure, for damaged case.

4.2.2 Units which utilise thruster-assistance, as an aid to position keeping or as a means of reducing anchor line tensions which have a system approved by LR, may be assigned a special features notation as defined in *Pt 3, Ch 10, 1.2 Class notations*.

4.2.3 The requirements of *Pt 3, Ch 10, 13 Thruster-assisted positional mooring* and *Pt 3, Ch 10, 14 Thruster-assist class notation requirements* are to be complied with and for the majority of offshore units with positional mooring systems which utilise thruster-assistance the class notation **TA(3)** will be applicable. Thruster-assist notations **TA(1)** and **TA(2)** will only be considered for applications of low criticality.

4.3 Design combinations of return periods of environmental parameters

4.3.1 Unless agreed otherwise with LR, the following design environmental combinations are to be considered:

(a) For floating offshore installations at a fixed location:

100-year sea state + 100-year wind + 10-year current.

For mobile offshore units:

50-year sea state + 50-year wind + 10-year current.

(b) For floating offshore installations at a fixed location:

100-year sea state + 10-year wind + 100-year current.
For mobile offshore units:
50-year sea state + 10-year wind + 50-year current.

(c) In locations subject to squalls:

For floating offshore installations at a fixed location:
100-year squall + 1-year sea-state + 1-year current.
100-year squall + no other environment.
For mobile offshore units:
50-year squall + 1-year sea-state + 1-year current.
50-year squall + no other environment.

When specialist environment reports adequately provide determined joint probabilities of occurrence of the various local environmental actions (wind waves, swell, wind, current), the design may be based on investigation of the mooring system response to each dominant environmental action with return period of 100 years and associated other actions (e.g. 100 year wind wave plus associated swell, wind and current).

Combinations of environmental parameters of lower return period may govern the response of the positional mooring system and as such combinations of environmental parameters with lower return period may need to be considered to ensure the worst response of the positional mooring system is captured in the design analyses.

In locations where both wind driven waves and swell prevail, the sea state report is to consider the 100 years (or 50 years for Mobile Offshore Units) wind driven waves with associated swell and 100 year (or 50 year as applicable) swell with associated wind driven sea.

In locations subject to cyclonic events the above combinations are to be extended to investigate both cyclonic and non-cyclonic conditions.

4.3.2 When the specialist environmental data report indicates stronger correlation between wind, wave and current, (e.g. concurrent occurrence of all environmental parameters at same return period) the above design environmental condition may need to be amended.

4.3.3 For 100-year (or 50-year for mobile offshore units) waves, a range of different wave height and period combinations shall be considered.

(a) To ensure that the most critical combinations of low frequency and wave frequency responses are determined, a broad range of sea states represented by significant wave heights and peak periods will required to be investigated and be preferably based on the use of a contour of significant wave height and peak period joint frequency distribution at 100-year return period (or 50-year contour for mobile offshore units).
(b) When contours of significant wave heights and peak periods are not reported in the environmental data report, a conservative range of wave heights and period range will require to be applied in the design (*see Pt 3, Ch 10, 3.4 Environmental parameters 3.4.3*).
(c) As the wave spectrum is a combination of wind-driven waves and swell, consideration will need to be given for certain locations to the joint occurrence and angular separation between these two components. Appropriate hindcast data can be used to this effect.

See also Pt 3, Ch 10, 3.3 Metocean data 3.3.2 and *Pt 3, Ch 10, 3.4 Environmental parameters 3.4.3*.

4.3.4 For a unit and/or ship designed to disconnect from the mooring system, appropriate lower limiting environmental conditions can be applied for the connected cases.

4.3.5 The mooring system with the unit and/or ship disconnected is normally required to be designed for the criteria specified in *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.1* to *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.3*.

4.3.6 Specific combinations of environmental conditions need to be set as design limits for temporary operations where these operations may overload the positional mooring system in environmental conditions less severe than those considered in *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.1* to *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.3*. The design shall check and confirm that specific operations (e.g. side by side or tandem loading or offloading or connection or disconnection of OU from PMS (disconnectable cases)) carried out within specific

environmental limits, do not result in overloads in the positional mooring system. The limiting environmental criteria for specific operations should be reported in the operation manual.

4.3.7 Note that account is to be taken in the design of build-up of marine growth on the anchor lines, riser system and/or the hull, and the resulting increase in load and damping.

4.4 Design directional combinations of environmental parameters

4.4.1 Sufficient combinations of directions of wind and current relative to wave direction are to be investigated to ensure the critical cases are found. Swell is to be superimposed from the worst case direction, *see Pt 3, Ch 10, 3.4 Environmental parameters 3.4.3*. The following combinations are envisaged as a minimum for design (unless joint directional probabilities of the various environmental actions are available and can be adequately documented or more onerous directional combinations are reported in a specialist report):

(a) Wave, wind and current collinear.
(b) Wind and current at 30° to waves.
(c) Wind at 30° to waves, and current at 90° to waves.

Note.

For case (c) above, only combination (a) given in *Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.1* has to be considered.

For locations where swell direction differs from that of the wind driven waves this directional separation is to be considered.

4.4.2 For locations subject to squalls events, squalls are to be considered. For all possible directions relative to waves and current unless directionality of squall event is sufficiently substantiated in a specialist report (*See Pt 3, Ch 10, 3.4 Environmental parameters 3.4.2*). The range of concomitant wave and current directions is to be agreed with LR (*See Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.1*). At the approach of squalls the directionality of the wind may change rapidly. The resulting transient responses of the offshore unit and its positional mooring system are to be investigated as required.

4.4.3 For locations subject to cyclonic events, the directionality of the dominant environmental parameters may change rapidly, resulting in transient responses of the offshore unit and its positional mooring system which are to be investigated as required.

4.5 Environmental directions relative to unit and mooring system

4.5.1 For spread moored units, at least head, quartering, beam and down-line directions are to be considered in mooring analysis. Depending on the symmetry of topside structure, super-structure and positioning mooring system, as well as on response analysis and wind, wave and current force/moment calculations, other directions may require to be considered, *see also Pt 3, Ch 10, 4.4 Design directional combinations of environmental parameters*.

4.5.2 For weathervaning units, the following cases must be considered as a minimum requirement:

- Wave direction along mooring line.
- Wave direction between mooring lines.

Additionally for locations subject to squalls:

- Squalls blowing in direction along mooring line.
- Squalls blowing in direction between mooring lines.

4.5.3 Where the mooring lines are grouped, additional wave directions will require to be considered at intermediate headings between the directions given above.

4.5.4 For a positional mooring system without thruster assist:

(a) the single line failure case shall investigate:

- loss of highest loaded line leading to highest excursions; and
- loss of second highest loaded line leading to highest line tensions.

(b) the two lines failure case shall investigate:

- loss of either line adjacent to the first failed line.

The assessment of the highest and second highest loaded line are to be based on stable statistics. For asymmetrical mooring configuration due consideration is to be given to the determination of the most onerous line breakage case leading to worst offset and line tension. Additional single and two lines failure cases may need to accounted to check minimum clearances (e.g. in case the worst offset cases do not correspond to the worst clearance). *See also Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.1*.

4.5.5 For locations subject to squalls, the environmental directions relative to the unit are to be based on a specialist report or a full 360° screening to ensure the worst condition is captured. As the direction of the wind during a squall can significantly and rapidly change, the effect of shift in the wind direction as the squall reaches the offshore unit is to be investigated giving due consideration transient shift in heading of offshore units that weathervane.

4.6 Other design aspects

4.6.1 Anchor lines are to have adequate clearance from subsea equipment such as templates, flowlines, adjacent fixed structures or other floating units and their subsea equipment. In general a minimum clearance of 10m is to be maintained at all times between the Offshore Unit inclusive of its other mooring lines and all other neighbouring floating, fixed or subsea structures. Acceptability of smaller clearance would need to be substantiated by an appropriate risk assessment. Where mooring line failure could lead to fouling of other structures (e.g. PLEM, pipelines, risers, flow-lines etc) a risk assessment is to be carried out. It is the responsibility of the Owner to notify the local authority or regulator, LR and the Owner of the other structures of the low clearance and any associated risks for the nearby asset. The design shall also check clearance (considering most onerous offset and damaged stability conditions, connection or disconnection operation etc.) between the Offshore Unit and its positional mooring system between components of the positional mooring system or account for the interaction through detailed design.

4.6.2 The design of the mooring system is to take account of the offset limits required by the drilling string or riser system, and the avoidance of contact between risers and anchor lines or other structures.

4.6.3 Where normal production, or other normal operational activity, is intended to be continued during periods where an anchor line is disconnected for planned inspection, maintenance or repair etc., specific environmental limitations are to be established to ensure that safety factors are maintained even with one line out of action. Such arrangements and the specific environmental limitations are to be reflected in the Inspection, Maintenance and Repair Manual and Operation Manual. The PMS Inspection, Maintenance and Repair plan is to ensure that scheduling of such IMMR activities be subject to an HAZOP type risk assessment (and account for potential hazard from squall, cyclonic event, etc.).

A similar procedure applies when machinery and equipment cannot remain fully functional during maintenance and inspection.

4.6.4 Wherever practicable, permanent moorings are to be designed to allow removal for repair in reasonable weather of damaged components without seriously reducing the overall safety of the unit as a whole.

4.6.5 In cases where the mooring system is intended to be actively controlled by adjustment of line lengths and tensions, satisfactory evidence must be submitted to show that the adjustment procedure is practical, taking account of winch control and prevailing environmental conditions. The risk associated with such arrangements and operational practice would need to be assessed using HAZID, HAZOP, etc.

4.6.6 Where units are moored in areas where high velocity currents occur, dynamic excitation due to vortex shedding associated vortex and wake induced vibrations are to be considered. This will affect both the global response of the Offshore Unit as well as the mean line tensions and the line dynamics of its positional mooring system.

The effects may be more significant as water depth increases.

4.6.7 The mooring line interaction with support structures such as stoppers, fairlead, hawse pipes, guide tubes is to be subject to detailed assessment of actions and reactions between mooring components and the support structure to enable detailed design of the interacting structures.

Aspects such as compression, bending, torque, friction, bearing pressure, grip pressure, chaffing, locking, wear, electrical continuity and effect on corrosion control of the components should be considered and documented as appropriate in the detailed design of the components.

4.6.8 The maximum allowed thickness of marine growth taken into account is to be stated in the Operations Manual. The actual marine growth should be monitored in service and the plan for regular cleaning (consistent with design assumptions) is also to be included in the Operation Manual. Marine growth is not to exceed the maximum allowed thickness in service.

4.6.9 When a positional mooring system is found damaged, it shall be promptly reported to the LR and a Condition of Class will generally be recorded. For normal production, or other normal operational activities to continue under Class, the Owner shall reassess the normal operations and demonstrate that the Offshore Unit still meets after damage the level of safety required by

Class Rules for intact and damaged (i.e. with one further line failed) conditions allowing for agreed documented mitigation measures (as per mooring failure response procedures) to be put in place. The Offshore Unit operating on Positional Mooring System with one line damage shall not present a risk of major hazard.

4.6.10 Consideration should be given to providing redundancy in the positional mooring system, to avoid potential disruption of normal production or other normal operation when a single failure or damage is found. This applies to the PMS in general (i.e. mooring lines, mooring equipment, integrity monitoring system and instrumentation etc.).

■ *Section 5*
Design analysis

5.1 General

5.1.1 A comprehensive analysis will be required in all cases and model tests are normally to be performed for ship shape units or unique designs. Validation will be required for each part of the analysis process, by correlation with model tests or other proven method.

5.1.2 Analytical procedures and numerical methodologies and models used in the analyses are to be described and shown capable of capturing the physical phenomenon pertinent to the specific design. Industry recognised proprietary software or in-house software may be used for the analyses. The original developer is expected to have performed adequate validation and verification of the software, and to readily provide evidence of such validation. In-house software needs to be shown to have been adequately calibrated and validated against model tests data, field measurements, or the results of other already validated industry-recognized software. Indicative accuracy of analytical and numerical tools used in the design analyses of the unit's response are to reported.

5.1.3 The use of validated numerical tools and software does not generally exempt the design from the need to calibrate and validate the project specific models.

5.2 Model testing

5.2.1 Consideration may be given to dispensing with specific model test requirements when the design is shown to be similar in all design and environmental parameters to that of an existing unit which has undergone model testing. The designers must provide evidence of this and justification for the request, as well as report the alternative methodology proposed for calibrating and validating the project specific numerical models. Any scaling techniques used for this must also be detailed. The request is to be submitted to LR for review and consideration for acceptance at an early stage of the design.

5.2.2 In general model tests are to address both sea keeping and station keeping aspects. The model test programme and test facilities are to be to LR's satisfaction. The model test programme and specification are to be submitted for review by LR and acceptance prior to the test campaign. Model test specifications and reporting for wave basin, wind tunnel and ice tank testing are to be in accordance with *Pt 4, Ch 1, 4.6 Model test specifications and reporting*.

The purpose of the model tests is to be well defined and generally is to enable calibration of key input parameters to the positional mooring system numerical model, validation of numerical modelling results, identification of unpredicted motion phenomena, assessment of complex loadings which are difficult to model numerically and evaluation of wind and current coefficients.

5.2.3 It is recommended that preliminary analyses be performed prior to the start of the model test programme, in order to understand and clarify the conceptual design, and to help focus the model testing on the most important design parameters.

5.2.4 Estimating wind forces and moments for design input into analysis or model basin wind fields should preferably be done on the basis of wind tunnel tests using an accurate project-specific model. *see Pt 4, Ch 1, 4.6 Model test specifications and reporting*.

5.2.5 The design philosophy of units intended to be moored in regions subject to sea ice or icebergs is required to be defined, including any quick-release mooring system arrangements.

5.2.6 The requirements for units intended to be moored in regions subject to seismic events, such as earthquakes or tsunamis, will be subject to special consideration.

5.3 Analysis aspects

5.3.1 The analysis is to take account of the following:

- The effect of current on wave drift force.
- The effect of water depth on current forces, first order responses and wave drift.

5.3.2 The mooring line dynamic behaviour is to be accounted for in the station keeping analyses, taking into account the components mechanical and hydrodynamic characteristic properties such as mass (where appropriate inertia), drag and added mass (where appropriate added inertia) and elasticity.

5.3.3 Weight and elasticity properties of anchor lines are to be obtained from chain, wire or fibre rope manufacturers. While the mooring chain elasticity can be expected to be linear that of ropes may not be, especially fibre ropes. The non-linear stiffness properties are to be accounted for in the model.

Tolerances of these characteristics are be established and the information is to be documented and included in the submission. For chain parts of the mooring lines, properties are to be based on the total line diameter including corrosion allowance, *see Pt 3, Ch 10, 8.2 Corrosion and wear 8.2.1*.

5.3.4 The sensitivity of the simulated positional mooring system and the response of the Offshore Unit to these tolerances on line properties (inclusive of expected variations of these over the service life, effect of corrosion, and marine growth) are to be carried out to ensure the resulting responses remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances). Similarly the analyses are to investigate the sensitivity of responses to variations in assumed drag and inertia coefficients of the mooring lines.

5.3.5 The effect of mooring line interaction with soil is also to be taken into account in the station keeping analyses. Consideration is to be given to the local bathymetry, sea-bed slope (or specific profile), sand wave phenomena (and associated changes in mooring line seabed support and embedment), friction (in-line and lateral) between the line and potential in service scouring or dig-in in the touch down region.

Sensitivity of the simulated positional mooring system and the response of the Offshore Unit to these soil-mooring line interactions (that may occur over the service life) is to be carried out to ensure the resulting responses remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances).

5.3.6 The offshore unit station keeping analyses is also to take into consideration manufacturing (e.g. length, stiffness) and installation tolerances (e.g. anchor location, potential remaining slack in the line after installation or in inverse catenary of the buried line section close to the anchor) as well as precision and accuracy of survey/inspection techniques intended to be deployed in service to confirm the positional mooring system configuration and integrity.

The positional mooring system design is also to ensure that the simulated positional mooring system and the responses of the Offshore Units remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances) when these uncertainties are considered.

5.3.7 When, after installation, the positional mooring system, Offshore Unit, structure and equipment etc. are found to significantly differ from what was accounted for in the design, as-installed station keeping analyses will need to be carried out to confirm compliance with these Rules.

5.3.8 For positional mooring systems using fibre ropes, analyses methodologies are to be submitted to LR for acceptance. The recommendations of API RP 2SM are to be taken into account in analyses methodologies to ensure conservative estimates of mooring line tensions and the offsets of the offshore unit. Due attention is to be paid to the non-linear dynamic behaviour of the ropes, frequency dependent stiffness characteristics and the delayed elastic stretch and delayed elastic recovery characteristics of the ropes. The analyses are to investigate the sensitivity of the responses to these input parameters.

5.4 Analysis

5.4.1 The following analyses, which may be combined, are to be carried out and submitted to LR:

- Hydrodynamic analysis of the offshore unit.
- Heading analysis (for Offshore Units that weathervaning about single point mooring or whose heading significantly varies with environment directionality and conditions).
- Motions analysis of the moored unit.
- Mooring analysis.

5.4.2 Hydrodynamic analysis is required to establish the six degrees of freedom motion response amplitude operators (RAOs) of Offshore Units.

The response amplitude operators (RAOs) of the six degrees of freedom motions should be determined, covering a range of frequencies encompassing the wave spectra pertinent to the project (with sufficient refinement in increment around natural periods of responses) and headings covering 360° (unless symmetry can be used).

In general at least three different drafts or loading conditions should be considered taking due account of the site specific water depth. *Pt 3, Ch 10, 5.4 Analysis 5.4.2* illustrates such practice.

The six degrees of freedom motion RAOs are input to heading, motions and mooring analyses.

Generally the hull of large offshore units should be modelled with 3D-diffraction elements and validated first order radiation-diffraction numerical software can be used in the derivation of the RAOs of the six degrees of freedom motions of the offshore unit. While for simple catenary mooring line configurations in shallow to medium water depth configurations, the positional mooring system can generally be assumed to not significantly affect the first order motions of the offshore unit, such assumptions may not apply to offshore units in moored in deep water or when using semi-taut to taut mooring lines configurations. Thus the validity of such assumptions are to be checked and, when necessary, coupled analysis be used.

Note: RAOs of motions from linear radiation-diffraction analyses are used as input to heading, motions/offset and mooring analyses. The RAOs generally only consider potential damping and as such, when looking at actual responses, viscous damping contributions from such effects as skin friction, vortices etc. needs to be input separately in heading, motions, mooring analyses. The additional damping input shall be documented.

Table 10.5.1 RAO Parameters

	From	To	Increment	Notes
Frequency (rad/s)	0.1	1.5	≤ 0,05	Refinement around natural periods to be considered.
Heading (degrees)	-180	180	≤ 10	Linear interpolation. Refining around singular headings.
Loading Condition	Fully Loaded	Ballasted	At least one intermediate	Most onerous conditions in service and transit conditions to be considered.

5.4.3 Heading analysis is generally used in load response analysis in the structural assessment of weathervaning ship type offshore units as part of the LR ShipRight Procedure for Ship Units to establish response parameters and design waves. It may also be used in support of motions and mooring analyses to assess the mean heading of the unit relative to environment parameters to be used in the station keeping analyses and fatigue analyses.

It requires a set of hindcasted environmental data (*see Pt 3, Ch 10, 3.3 Metocean data 3.3.2*).

The mean heading of the unit is to be calculated for each sea-state considering the action of the wind sea, swell, current and wind. The hull is to be modelled with 3D-diffraction-radiation elements at a minimum of three draughts representative of all loading conditions. The effects of current, drag loads and wind loads on the hull should be represented by current force coefficients and wind force coefficients. The current force coefficients should be derived from model tests (or the OCIMF data [Mooring Equipment Guidelines] when applicable). The wind force coefficients should preferably be based on values from model test results (for ship shape hulls preliminary analyses may use wind coefficients from the OCIMF data [Mooring Equipment Guidelines] corrected as appropriate for topsides structures).

For offshore units with thruster assisted heading control, both fully operational and single failure is to be considered.

The following information on the directionality of the environment relative to the offshore unit can generally be derived and used to substantiate the conservatism of the directional combinations of environmental parameter proposed in *Pt 3, Ch 10, 4.4 Design directional combinations of environmental parameters 4.4.1* and assist in the selection of fatigue design load cases:

- relative direction of the offshore unit and environmental parameter (wind, wind driven waves, swell, current)
- sea state Mean and Standard Deviation, Skewness and Kurtosis of Relative Heading as a function of Significant Wave Height
- (differentiating swell and wind driven waves)
- wind sea direction against wind sea Hs;
- swell sea direction against swell sea Hs;
- wind direction against wind speed;
- current direction against current speed.

5.4.4 Motion analyses of the moored unit focus on assessing the characteristic motion response of the Offshore unit within envelopes of design environmental conditions, *see Pt 3, Ch 10, 4 Design aspects*.

The analyses are to investigate a large set of stationary (typically 3 hours) environmental conditions to enable the estimation of maximum offsets (horizontal motions primarily associated with surge, sway and yaw of the unit) but also the maximum heave, roll and pitch.

As may be required by the specific positional mooring system and offshore unit design and operations, the motion analyses may also need to focus and investigate motions in relation to specific criteria such as clearance criteria (e.g. for external turret moored units potential overshoot in surge motion requires special consideration).

The model for the motion analysis should include restoring characteristics and damping contributions from:

- Positional mooring system.
- Thruster system.
- Risers or umbilical system

The motion analysis should generally be based on time domain simulations. Frequency domain analyses may be acceptable when non-linear or coupling effects are not significant, subject to sufficient model test or field data calibration confirming the validity of the analysis and agreement with LR.

When linearization techniques are used they should be fully documented and shown to have insignificant impact on the motion responses for the environmental conditions considered.

The following component of the global motion responses shall be derived from the analyses:

- mean offsets from wind, current and wave drift steady force loads.
- low frequency offsets from 2nd order wave drift loads, and wind gust loading (and when significant the associated accelerations).
- wave frequency motions and accelerations from oscillatory response of the unit to the first order wave loads.
- vortex induced motions induced by flow over slender or sharp edged structures (*see Pt 3, Ch 10, 4.6 Other design aspects 4.6.6*).

The effect of the mooring system on the first order wave frequency motion responses may generally be ignored (for positional mooring systems using loose catenary mooring line configuration in shallow to medium water depth). Similarly the effect of riser and umbilical systems on the first order wave frequency motion responses may generally be ignored for traditional compliant configurations in shallow to medium water depth). These effects may become significant in deeper water in which case, coupled analyses should be conducted to verify the motion responses for the estimate of maxima. When part of the hull of the offshore unit is slender, small in comparison to wave lengths to be considered, or presents sharp edges, viscous effects are to be considered and included in the analysis. For example on ship shape hulls, linearised roll damping should be calculated for each sea-state using a published method and the results verified with model tests.

Low frequency motion responses occurring close to the natural frequency (e.g. surge motions of ship-shaped FPSO) are quite sensitive to damping contributions from mooring lines and risers. These should be accounted for in the analyses, generally including the effect of line dynamics to the analysis. Damping input to the analyses model, its calibration and validation against pertinent model tests or full scale data should be reported in detail.

Local constraints to the sea water or wind flow or obstacles in the vicinity of, or attached to, the offshore unit or its moorings that may cause interferences should be given special consideration.

5.4.5 Mooring load analyses are to address both loads acting on mooring lines (and their components) and loads the mooring lines impart on support structures of the offshore unit and mooring line attachment points.

The resulting loads for each stationary environmental condition considered should be described in terms of their steady mean component, low-frequency component and wave frequency component.

The oscillatory component should be statistically described with standard deviations and distribution of peak responses and enable the estimate of maximum (or minimum values).

Results should include in-line tensions, but also where necessary at component interfaces forces and moments. The analyses should enable derivation of the loads (forces and moments) acting on components, as required for input to the detailed design of the components.

Mooring load analyses are often combined with motion analyses of the moored unit as the characteristic motions of the mooring lines attachment points on the unit are required to be modelled to the same extent as can be derived from the motion analyses of the moored unit.

Mooring load analyses should provide all necessary load characteristics for the verification of the mooring lines global performance and detailed design of the mooring line components and support structures. The mooring load analyses are generally to be carried out in time domain to capture the non-linear dynamic behaviour of the lines.

The main non-linearities in the mooring line responses typically arise from:

- large changes in the line geometry as it stretches, (inherent to catenary configuration or lines with buoyancy elements).
- axial stiffness of the components (e.g. fibre ropes).
- viscous fluid flow interaction (through drag and added mass) with mooring line components.
- soil interaction effect through axial and lateral friction effects on line motion on the sea bed.

Frequency domain analyses may be acceptable when non-linear or coupling effects are not significant, subject to sufficient model test or field data calibration confirming the validity of the analysis and agreement with LR.

When linearization techniques are used they should be fully documented and shown to have insignificant impact on the load responses for the environmental conditions considered.

The mooring lines model should be representative of the weight and buoyancy, geometric, mechanic and hydrodynamic properties of the various components and their assembly.

The mooring line layout should take into consideration the location of the anchor points to the sea bed, as well as the location of the attachment point on the unit and mooring line pretensions, the unit's draft, water depth and seabed morphology.

The mooring lines component drag and inertia characteristics can generally be modeled using a Morison formulation.

Due consideration should be given to potential onset of vortex shedding along the line and associated loads and vibrations arising from these. This can significantly affect drag characteristics of the mooring lines.

5.4.6 For offshore units operating in areas subject to squalls special consideration should be given to the transient nature of the load and motion responses. Generally squalls are considered to reach the moored offshore unit from any direction at any time during otherwise stationary environmental conditions. The analyses should investigate a sufficient number of squall cases (for various squall time traces) to enable to establish maxima of responses. While such analyses require substantial number of cases to be considered, the analyses duration needs only to be sufficient to capture the transient squall wind loading and associated response of the moored unit. Care should be taken to ensure that the peak responses are captured.

5.4.7 For low frequency response analysis, the non-linear stiffness characteristics are to be satisfactorily represented. The amplitude of low frequency motion will be highly dependent on system damping from the following:

- Current.
- Wave drift.
- Viscous effects on the hull.
- Anchor lines and risers.
- Wind effects.

Thruster damping may also be applicable in relevant cases and the basis for the damping terms used in the analysis is to be documented and submitted.

5.4.8 Tensions due to low frequency, and wave frequency excitation can be computed separately. The effect of line dynamics is to be accounted for in wave frequency analysis. Low frequency tension can be based on quasi-static catenary response. Wave frequency dynamic line tension is to be computed at alternative low frequency offset positions, *see Pt 3, Ch 10, 5.5 Combination of low and high frequency components – Design values 5.5.4*.

5.4.9 For dis-connectable positional mooring systems, analyses are required to simulate the transient connection and disconnection operations to ensure the responses (e.g. loads, slack, motions, clearances, potential overshoot or run-up etc.) are within design envelopes (*See also Pt 3, Ch 10, 4.3 Design combinations of return periods of environmental parameters 4.3.6*). Similar model as for motion or mooring analyses can be used. Generally the analyses should capture the various stages and configurations of the positional mooring system during such operation, cover a representative range of environmental conditions in which the operation may be initiated at any time. The transient nature, speed and duration of the operation should be taken in consideration in the analyses, as well as the level of controls (e.g. uncontrolled quick disconnect or control disconnect, re-connect), the load transfer, progressive coupling, decoupling of the Offshore Unit and its positional mooring system etc.

5.5 Combination of low and high frequency components – Design values

5.5.1 Maximum design values for offset and tension are to include nominal pre-set static values, steady component, and wave and low frequency contributions derived from combined wave frequency and low frequency dynamic response analyses. The time domain simulations are to be of sufficient length to establish reasonable confidence levels in the predictions of maximum response. When squalls are considered, the approach for selecting the design values of tensions and offsets is to be agreed with LR.

5.5.2 Symmetry of the positional mooring system can be accounted for in the estimation of maximum design values of offset and mooring line tensions to reduce the number of maximum design values to be considered in the design verification.

5.5.3 The most probable maximum values for tension and offset can be determined from the distribution of peak loads. The statistical basis and probability distribution (Rayleigh, Weibull, Gumbel, etc.) fitted to the peak responses from the analyses to derive the design maximum values is to be documented and submitted for review. For each response considered the expected average of maxima of multiple simulations and associated standard deviation, and the probability distribution used in the derivation of the most probable maxima are to be demonstrated to provide a good fit to the peak values.

Sensitivity of the maximum design values to the underlying assumptions (number of peaks, threshold etc.) should be documented.

When fitted distributions are not well defined or assumptions are not verified (e.g. narrow banded process assumption) a robust estimate expected maximum value (derived from multiple seed analyses) should be referred to in the design.

5.5.4 Tensions and offset values can be combined as follows, when low frequency and wave frequency analyses are conducted separately:

(a) **Offset:**

$$X_{\mathrm{MAX}} = X_{\mathrm{MEAN}} + X_{\mathrm{LF\ sig}} + X_{\mathrm{WF\ max}}$$

or

$$X_{\mathrm{MAX}} = X_{\mathrm{MEAN}} + X_{\mathrm{LF\ max}} + X_{\mathrm{WF\ sig}}$$

whichever is the greater

where

X_{MAX} = maximum vessel offset

X_{MEAN} = mean vessel offset

$X_{\mathrm{LF\ sig}}$ = significant low frequency offset

$X_{\mathrm{LF\ max}}$ = maximum low frequency offset

$X_{\mathrm{WF\ sig}}$ = significant wave frequencyl offset

$X_{\mathrm{WF\ max}}$ = maximum wave frequency offset.

(b) **Tension:**

$$T_{\mathrm{MAX}} = T_{\mathrm{MEAN}} + T_{\mathrm{LF\ sig}} + T_{\mathrm{WF\ max}}$$

or

$$T_{\mathrm{MAX}} = T_{\mathrm{MEAN}} + T_{\mathrm{LF\ max}} + T_{\mathrm{WF\ sig}}$$

whichever is the greater

where

T_{MAX} = maximum tension

T_{MEAN} = tension at mean vessel offset

$T_{\text{LF sig}}$ = significant low frequency tension

$T_{\text{LF max}}$ = maximum low frequency tension

$T_{\text{WF sig}}$ = significant wave frequency tension computed at maximum low frequency offset position, $X_{\text{LF max}}$

$T_{\text{WF max}}$ = maximum wave frequency tension computed at significant low frequency offset position, $X_{\text{LF sig}}$

5.5.5 Estimates of maximum design values can be based on the following:

(a) **Low frequency:**

$X_{\text{LF sig}} = 2\,\sigma_{\text{xLF}}$

$X_{\text{LF max}} = \sigma_{\text{xLF}}\sqrt{2(\text{InN}_{\text{LF}})}$

$T_{\text{LF sig}} = 2\,\sigma_{\text{TLF}}$

$T_{\text{LF max}} = \sigma_{\text{TLF}}\sqrt{2(\text{InN}_{\text{LF}})}$

where

$X_{\text{LF sig}}$ = significant low frequency offset

$X_{\text{LF max}}$ = maximum low frequency offset

$T_{\text{LF sig}}$ = significant low frequency tension

$T_{\text{LF max}}$ = maximum low frequency tension

σ_{xLF} = standard deviation of low frequency offset

σ_{TLF} = standard deviation of low frequency tension

N_{LF} = number of low frequency oscillations during short-term storm state (not less than 3 hour storm)

ln = $\log_{\text{e}}$

e = base of natural logarithms, 2,7183.

(b) **Wave frequency:**

$X_{\text{WF sig}} = 2\,\sigma_{\text{xWF}}$

$X_{\text{WF max}} = \sigma_{\text{xWF}}\sqrt{2(\text{InN}_{\text{WF}})}$

$T_{\text{WF sig}} = 2\,\sigma_{\text{TWF}}$

$T_{\text{WF max}} = \sigma_{\text{TWF}}\sqrt{2(\text{InN}_{\text{WF}})}$

where

$X_{\text{WF sig}}$ = significant wave frequency offset

$X_{\text{WF max}}$ = maximum wave frequency offset

$T_{\text{WF sig}}$ = significant wave frequency tension

$T_{\mathrm{WF\,max}}$ = maximum wave frequency tension

σ_{xWF} = standard deviation of wave frequency offset

σ_{TWF} = standard deviation of wave frequency tension

N_{WF} = number of wave frequency oscillations during short-term storm state (not less than 3 hour storm)

ln = $\log_e$

e = base of natural logarithms, 2,7183.

■ Section 6
Anchor lines

6.1 General

6.1.1 Anchor line length is to be sufficient to avoid uplift forces occurring at the anchor point for damaged condition loads, unless the anchor point is specially designed to accept a vertical component of loading.

6.1.2 An anchor line integrity monitoring system or device is to be provided for floating unit mooring systems, to detect line breakage and significant tension and offset irregularities under ambient environmental conditions as well as more severe storms within the envelope of design environmental conditions.

The mooring line integrity monitoring system shall be able to detect failure of any part along the line (between attachment point to Offshore Unit to at least the seabed touch down or embedment point.

Ability to detect line failure beyond seabed touch down or embedment should be assessed and documented. The results should be taken into consideration when setting the scope of Offshore In Water Survey.

The precision and accuracy of the system is to be documented for a load range up to at least 90% of the breaking strength of the mooring lines and 100% of the offset range.

Detection of tension anomalies or line breakage is to raise an alarm (at least visual). The system should be able to be interrogated on demand and present sufficient redundancy so that the system remains operational after failure of any one component and to enable inspection or testing, maintenance and repair without loss of operability.

Calibration checks are to be carried out at least once a year.

Calibration and maintenance procedures and schedule are to be documented in the Operation Manual of the unit.

This is generally not a requirement for offloading buoy systems.

6.1.3 Specific steel wire rope, chain and fibre rope design requirements can be found in *Pt 3, Ch 10, 7 Wire ropes*, *Pt 3, Ch 10, 8 Chains* and *Pt 3, Ch 10, 9 Fibre ropes* respectively.

6.1.4 In general, the break strength of the anchor line is not to be greater than the load bearing capacity of the connecting structure.

For chain or rope loose fittings, sockets, shackles, connectors etc. the design shall be based on mooring line pull at least equal to the as new nominal minimum break strength of the mooring line main component (steel wire rope, chain or fibre rope) applying a minimum contingency factor of 1.1.

For fairleads and stoppers *see Pt 3, Ch 10, 10 Fairleads and cable stoppers*. For support structure *see Pt 4, Ch 6, 1 General requirements*

6.1.5 In general the mooring analyses should provide all of the loading parameters required for the detailed design of the mooring lines components and the associated supporting structures they interact with (pad-eyes, fairleads, bend shoes etc). The detailed structural or mechanical design of complex or non-standard (e.g. special D-shackles with dimensions not conforming with ISO 1704, or special connectors) component is generally substantiated by finite element calculations. Suitable elastic plastic models need to be used to model elastic plastic behaviour (e.g. Ramberg-Osgood law) at the contact points. Convergence should

be demonstrated for the large displacement nonlinearities, contact related nonlinearities as well as nonlinear material properties. Alternatively elastic analysis is also acceptable.

The detailed design calculations of components should address both strength and fatigue aspects. For fatigue calculations principal stresses at the model mesh are to be refined at hot spots locations and at surface of the modelled component to ensure characteristic mean principal stresses in the surface plane are captured.

Special non-standard mooring components shall be designed so that local yielding only occur for a few load cycles imparting a shake-down effect after which no further yielding occurs. The analysis shall be based on cyclic material properties and cyclic loading shall demonstrate an effective shakedown after few cycles.

Deformation under design loads from (intact and one line damage case) shall not adversely affect the performance of the component.

Conservative plastic strain and stress curve and characteristics plastic strain limit shall be reported for the selected material with reference to recognised code or standard and substantiated by material test records.

6.1.6 Kenter links are not permitted on long term permanent mooring systems. Connectors purposely designed (for project specific strength and fatigue loading) (e.g. H-Links) and manufactured under LR Survey shall be preferred.

6.1.7 Locking mechanisms of pin parts of mooring line component connections on long term positional mooring systems should be redundant and not be located within the main load path.

6.2 Factors of safety – Strength

6.2.1 Minimum factors of safety applicable to the steel wire rope, chain and polyester anchor lines of moored floating units are given in *Pt 3, Ch 10, 6.2 Factors of safety – Strength 6.2.1*. For fibre ropes, *see Pt 3, Ch 10, 9.2 Design aspects 9.2.2*.

Table 10.6.1 Minimum factors of safety for anchor lines for floating offshore installations at a fixed location

Design case	Factor of safety, *see Note 2*	
	Intact	Damaged
Extreme storm, or maximum environment, with floating unit attached	1,67 *see Note 1*	1,25 *see Note 1*

NOTES

1. The factors of safety given in this Table are associated with the following conditions:

(a) Arrangements being available to shut down production and/or transfer of oil or gas through risers in event of anchoring system failure.

(b) The floating unit being located in an open sea area. Special consideration will be given to factors of safety when the unit is in close proximity to another installation, or is located near the shore.

2. Factor of safety = $\dfrac{\text{Anchor line minimum breaking strength}}{\text{Maximum tension}}$

Anchor line minimum breaking strength basis to be documented.

A reduction factor may require to be applied to the standard assigned minimum breaking strength of anchor line components in some cases (e.g., where component test database is small: for non-standard components), or where anchor line components are not new.

3. Maximum tension to be based on assessment by dynamic analyses. *See also Pt 3, Ch 10, 5.5 Combination of low and high frequency components – Design values 5.5.3* on maximum tension.

6.2.2 Factors of safety applicable to the steel wire rope, chain and polyester anchor lines of offshore loading buoys (CALMs, turret mooring buoys which may remain temporarily disconnected without mooring line integrity monitoring etc.) are given in *Pt 3, Ch 10, 6.2 Factors of safety – Strength 6.2.4*. For generic fibre ropes, *Pt 3, Ch 10, 9.2 Design aspects 9.2.2*.

6.2.3 **PM** notation (including **PM TA(1)**, **PM TA(2)** and **PM TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines for mobile offshore units are given in *Pt 3, Ch 10, 6.2 Factors of safety – Strength 6.2.4*.

6.2.4 **PMC** notation (including **PMC TA(1)**, **PMC TA(2)** and **PMC TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines for mooring system for mobile offshore units analysed quasi-statically and dynamically are given in *Pt 3, Ch 10, 6.2 Factors of safety – Strength 6.2.4*and *Pt 3, Ch 10, 6.2 Factors of safety – Strength 6.2.4* respectively.

Table 10.6.2 Minimum factors of safety for anchor lines of offshore loading buoys

Design case	Factor of safety	
	Intact	Damaged
Extreme storm, or maximum storm condition with ship attached	1,85	1,35

NOTES

1. For special cases where allowable offset criteria for risers cannot be met in a Damaged Case (single line break) (e.g. in offshore loading buoy systems for shallow water), the Damaged Case can be omitted in design and an increased intact factor of safety applied. A minimum factor of safety of 2,3 is to be applied in this case. Failure of any one mooring line should still be shown not lead to progressive collapse or incidents of substantial consequences such as loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking.

2. Maximum tension to be based on assessment by dynamic analyses. *See also Pt 3, Ch 10, 5.5 Combination of low and high frequency components – Design values 5.5.3* on maximum tension.

Table 10.6.3 Factors of safety for PM notation

Design case	Description	Factors of safety for **PM** notation, *see* Note 1	
		Quasi-static analysis	Dynamic analysis
1	Operating (Intact)	2,7	2,3
2	Survival (Intact)	1,8	1,5
3	Operating (Single line failure)	1,8	1,5
4	Survival (Single line failure)	1,25	1,1

NOTES

1. The factors of safety given in this Table apply to units positioned at least 300 m from another unit.

2. The unit is to be positioned to avoid contact with another unit in any of the design cases.

3. *See also Pt 3, Ch 10, 5.5 Combination of low and high frequency components – Design values 5.5.3* on maximum tension.

Table 10.6.4 Factors of safety for PMC notation - Quasi-static analysis

Design case	Description	Factors of safety for **PMC** notation Quasi-static analysis, *see* Notes			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	3,0	2,7	3,0	2,7
2	Survival (Intact)	—	—	2,0	1,8
3	Operating (Single line failure)	2,0	1,8	2,0	1,8

4	Survival (Single line failure)	—	—	1,5	1,33
NOTES					
1. *See also Pt 3, Ch 10, 5.4 Analysis*					
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.					
3. *See also Pt 3, Ch 10, 5.5 Combination of low and high frequency components – Design values 5.5.3* on maximum tension.					

Table 10.6.5 Factors of safety for PMC notation - Dynamic analysis

Design case	Description	Factors of safety for **PMC** notation Dynamic analysis, *see* Notes			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	2,5	2,3	2,5	2,3
2	Survival (Intact)	—	—	1,65	1,5
3	Operating (Single line failure)	1,65	1,5	1,65	1,5
4	Survival (Single line failure)	—	—	1,35	1,2
NOTES					
1. *See also Pt 3, Ch 10, 5.4 Analysis*.					
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.					

6.3 Fatigue life

6.3.1 The fatigue life of the main components in the positional mooring system are to be verified. Calculations are to be submitted.

6.3.2 Where applicable tension bending effects are to be considered in the fatigue calculations of the mooring line at the fairleads and stoppers (or at any point within the line where it is subject to a constraint resulting in local bending). The detailed methodology shall be reported and agreed with LR in the early stages of the design. Contingencies should be included to address any uncertainties.

Torsion in the mooring line shall be avoided by design. In cases where this is not possible the performance of the component under such loading regime should be substantiated by a qualification programme agreed with LR.

Note: For top chain connections to stoppers, guidance can be drawn from publications from recent joint industry research projects on Fatigue of Top Chain of Mooring Lines due to In-Plane and Out-of-Plane Bending). Details of the methodology shall be reported and agreed with LR at early stage of design. The associated scope of manufacturing and testing shall be agreed with LR. The bushing performance shall be well documented and substantiated by adequate prototype testing and confirmed by factory acceptance tests. The design shall include contingencies to address any uncertainties (e.g. long term performance of bushing, bush and interlink friction coefficients etc.).

(*see also Pt 3, Ch 10, 10.1 General requirements 10.1.11*).

Applicable factors of safety shall be agreed with LR, after review of the detailed design methodology (else the default is 10).

6.3.3 Fatigue life calculations for anchor lines can be carried out in accordance with a recognised Code, e.g., *API RP 2SK: Recommended Practice for Design and Analysis of Station keeping Systems for Floating Structures*.

> Note Where various wind driven wave and swell (potentially multiple) regimes prevail concurrently, the fatigue assessment shall be shown to account for these environmental characteristics and conservatively capture the various peak frequencies and relative directionalities.

6.3.4 Consideration will be given to the use of alternative methods, detailed proposals are to be submitted and agreed with LR.

6.3.5 The minimum factors of safety on the calculated fatigue lives for components of the mooring system are to comply with *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2* in *Pt 4, Ch 5 Primary Hull Strength* .

■ *Section 7* Wire ropes

7.1 General

7.1.1 This Section applies to steel wire ropes for positional mooring systems of offshore units.

7.1.2 Wire ropes, associated fittings, are to be of an approved design.

7.2 Rope construction

7.2.1 When selecting a rope construction the following considerations apply:

- Required service life.
- Position in catenary.
- Axial stiffness properties of rope.
- Bending over sheaves, etc.
- Characteristic torsional properties of rope construction.

7.2.2 Various rope constructions can be accepted for long-term mooring applications. These include:

- spiral strand.
- locked coil.
- six-strand.

Other constructions can be considered.

7.3 Design verification

7.3.1 The design of wire rope and associated fittings is to be verified. The following information will be required for appraisal and information:

- Plans of rope assembly, components and fittings such as terminations/sockets, bearings, pins and locking mechanism, bend stiffeners, electrical insulation and other fittings.
- Materials specification covering all components and fittings, steel wires, steel fittings, pins, socketing resins, sheathing and blocking or lubricating compound).
- Corrosion control specification (anodes, steel wire galvanisation, coating, electrical insulation, arrangement, and supporting calculations.
- Design specification.
- Purchaser's specification.
- Codes and Standards applied.
- Calculations for the strength and fatigue of rope, socket, fittings, and their corrosion protection.
- Dimensions of rope assembly and components and fittings as well as associated tolerances.
- Weight properties and tolerances (to include weight per metre of main rope section inclusive of sheathing).
- Axial and torsional stiffness data.
- Wire rope datasheet (inclusive of all rope main characteristics, tolerances, handling and service limiting criteria).

7.3.2 Data from prototype rope tests is to be submitted (inclusive of material, construction and test procedures and data)..

7.3.3 Fatigue life calculations for steel wire ropes can be carried out in accordance with a recommended Code, e.g., *API RP 2SK: Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures*. Rope bending fatigue effects are to be included where relevant.

7.3.4 The minimum factors of safety on the calculated fatigue lives of wire rope and fittings are to comply with *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2* in *Pt 4, Ch 5, 5.6 Factors of safety on fatigue life*.

7.3.5 The rope termination including the socket, socketing arrangement and pin is to be designed to withstand a load of not less than the minimum breaking strength of the attached wire rope and be shown to withstand no significant plastic deformation under loading equal to 80 per cent of this load.

The rope is to be designed for the maximum design, storage and installation conditions specified for the project.

7.3.6 Pin locking mechanism, anodes and bend stiffeners attachment to the sockets should not be in the main load carrying path of the socket.

7.3.7 Sheathing should be able to match and accommodate the rope flexure and elongation under rope design and service loads without loss of integrity. The sheathing should not rotate in relation to the sockets and be designed for the maximum grip pressure under various tensions specified for the project.

7.3.8 Bend stiffeners and their connection to sockets shall be designed to protect the wire rope end termination from over bending under design loads (including storage, installation and service) for the range of off line pull angles or curvatures specified for the project.

7.3.9 Bend stiffener connections to sockets should be adequately protected against corrosion.

7.4 Materials

7.4.1 Steel wire used for rope manufacture is to be manufactured in accordance with a recognised National Standard:

(a) The steel is to be of homogeneous quality, consistent strength, and free from visual defects likely to impair the performance of the rope.

(b) The minimum tensile strength of the wire is to be the tensile strength ordered. The maximum tensile strength is not to exceed the specified minimum strength by more than 230 N/mm^2. The tensile strength should normally be within the range 1420 to 1770 N/mm^2.

7.4.2 The material used in the manufacture of sockets is to comply with the following requirements:

(a) **Cast sockets:**

- Castings are to be manufactured and tested generally in accordance with *Ch 4 Steel Castings* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).
- As a supplement to *Ch 4 Steel Castings* of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative casting standards to *Ch 4 Steel Castings* of the Rules for Materials complying with recognised national or proprietary specifications may be accepted, *see also Ch 4, 1.1 Scope* of the Rules for Materials.

(b) **Fabricated sockets:**

- Plate material to be Grade D or DH quality in accordance with *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* of the Rules for Materials. Increased material toughness may be required in some cases.
- Plate with through thickness properties will generally be required, in accordance with *Ch 3, 8 Plates with specified through thickness properties* of the Rules for Materials.

(c) **Socket pins:**

- Socket pins may be cast or forged. Where cast, material requirements are to comply with (a) above. Forged socket pins are to be manufactured in accordance with *Ch 5 Steel Forgings* of the Rules for Materials.
- As a supplement to *Ch 5 Steel Forgings* of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative standards to *Ch 5 Steel Forgings* of the Rules for Materials, complying with recognised national or proprietary specifications may be accepted, *see also Ch 5, 1.1 Scope* of the Rules for Materials.

7.5 Corrosion protection

7.5.1 Wire ropes are to be protected against corrosion. The corrosion protection will normally consist of galvanising or other sacrificial coating of individual wires. Filler wires of zinc or other suitable sacrificial material can be incorporated in the outer layers of the rope, as an addition to, but not in place of, galvanising of individual wires.

7.5.2 Galvanising is to meet the following minimum standards:

(a) Zinc:

- BS EN 1179.

(b) Zinc weight:

- ASTM A 603 Table 5, Class A (spiral strand and locked coil).
- ISO 2232, Quality B (six-strand ropes).

(c) Alternative recognised Codes or Standards providing acceptable equivalence will be considered.

7.5.3 Sockets are to be protected against corrosion by sacrificial anodes or acceptable equivalent.

7.5.4 Suitable arrangements are to be made to insulate the corrosion protected rope/socket assembly from adjacent non-protected elements in the system.

7.5.5 Polyethylene sheathing can also be used on appropriate rope constructions, as an addition to, but not normally as an alternative to, galvanising:

(a) Where sheathing is intended to be fitted, the specification is to be submitted. ASTM D 1248 is an acceptable specification for medium or high density polyethylene sheathing.
(b) A continuous strip of contrasting colour is to be incorporated into the sheathing to aid monitoring for twist. The position of the strip around the circumference sheathing in relation to a reference point on each end socket should be reported on plan.

7.5.6 Compound used as blocking or lubricating material shall as a minimum meet the requirements ISO 4346 Steel Wire Ropes for General Purposes - Lubricants - Basic Requirements or equivalent.

7.5.7 Compound must not adversely affect the long term integrity of the wires and sheathing.

7.6 Manufacture and testing

7.6.1 Steel wire ropes are to be manufactured in accordance with the design standards and procedures and at a works approved by LR. Ropes and fittings will be subject to LR survey during manufacture and testing.

A prototype testing programme is to be agreed with LR and carried out under LR survey. Prototypes are to be of the same materials, construction and termination unless specifically agreed with LR.

7.6.2 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR's Surveyors.

7.6.3 Where sheathing is specified, it is to be carried out in accordance with the Quality Plan.

7.6.4 Cast sockets are to be manufactured and tested in accordance with the requirements of *Pt 3, Ch 10, 7.4 Materials 7.4.2*.

7.6.5 The following minimum requirements for the non-destructive testing of cast sockets are applicable:

(a) **Ultrasonics**: All areas of all sockets and pins.
(b) **Radiography**: Critical areas of first, last, and one intermediate socket selected by the LR Surveyor to be examined. Critical areas to be identified on design drawings, and these to be included in the design submission for verification.
(c) **Magnetic Particle Inspection (MPI)**: 100 per cent of all sockets and pins.
(d) **Visual**: 100 per cent of all sockets and pins.

7.6.6 The material of plate fabricated sockets is to comply with *Pt 3, Ch 10, 7.4 Materials 7.4.2* and welding and NDE to be in accordance with *Pt 4, Ch 8 Welding and Structural Details*. Post-weld heat treatment to be carried out for thicknesses exceeding 65 mm.

7.6.7 Tests are to be carried out on individual wires for the following:

Tensile strength and elongation.
Torsion.
Reverse bend.
Zinc coating; mass, uniformity and adhesion.

Tests are to be carried out in accordance with recognised National Standards such as ISO 2232, and ASTM A603, as appropriate.

7.6.8 Rope production samples are to be tested for the following:

Modulus.

Minimum breaking strength.

7.6.9 The tests required by *Pt 3, Ch 10, 7.6 Manufacture and testing 7.6.8* are to be as follows:

(a) The modulus test is to be carried out on one finished rope sample taken from the first production length. Production sockets need not be fitted for this particular test. Load/extension characteristics and permanent stretch are to be determined and documented. Acceptance criteria for permanent stretch are to be as follows:

Maximum of 0,4 per cent for spiral strand and locked coil ropes.

Maximum of 0,8 per cent for six-strand ropes.

The modulus of elasticity is to be calculated and documented. The basis for the calculated value (cross-sectional metallic area, or area of circle enclosing the rope) is to be clearly stated.

(b) Breaking load test is to be carried out on one sample taken from each manufactured length.

- Where the rope design, the machine, and the machine settings are identical, consideration can be given to a reduction in the number of tests. As a minimum, breaking load tests are to be carried out on a sample taken from each of the first manufactured length, and one other length, selected by LR Surveyors.
- Tests are to be carried out in accordance with a recognised National Standard such as EN 12385-1 Steel wire ropes – Safety – Part 1: General requirements (method 1).
- One of the rope samples is to be fitted at one end with a socket taken from the project production batch, and socketed in accordance with approved procedures. Where more than one socket design type is involved, a further assembly is to be tested for each different type of socket.
- The rope sample and the production socket is to withstand the specified minimum breaking load.

  The socket pin is to be able to be removed after the test, and replaced, without the application of undue force.
- NDE to be carried out on the socket following testing (100 per cent visual and 100 per cent MPI).

7.6.10 Socketing is to be performed according to the quality plan and is to follow a tested and repeatable procedure drawing on ISO 17558 'Steel wire ropes - Socketing procedures - Molten metal and resin socketing' and be carried out by experienced personnel.

Due attention should be paid to the following parameters:

- rope termination brush configuration,
- cleanliness of socket and rope brush,
- resin mix and mixing technique,
- brush and socket positioning and alignment,
- resin pouring technique,
- control of temperature and duration of curing,
- scale effect.

7.6.11 The characteristic mechanical properties (e.g. modulus of elasticity, shrinkage, compressive strength) of the socketing resin shall be established from a number of test samples. Guidance on tests methods can be drawn from BS 6319 Testing of Resin Compositions for Use in Construction (especially Part 1, 2, 5 and 12).

- resin compressive strength and modulus of elasticity (also ISO 604 Plastics – Determination of compressive properties).
- shrinkage
- density and hardness (also EN 59 Glass reinforced plastics – Measurement of hardness by means of a Barcol impressor).

The number of test samples is to be such as to establish the properties with sufficient confidence

7.6.12 Bend stiffeners are to be manufactured according to a quality plan and follow a qualified and repeatable procedure. Material properties (e.g. tear strength, elasticity, water absorption, aging) are to be reported.

7.6.13 The maximum allowable curvature of the wire rope under storage, service and installation conditions are to be substantiated and documented by the manufacturers.

7.6.14 Material properties (e.g. elasticity and water absorption) of the sheathing are to be documented. The sheathing should be manufactured such that it does not rotate in relation to the wire rope and sockets. The manufacturer is to substantiate and report curves of maximum allowable grip pressure under various tensions for the sheathed rope provided.

7.6.15 Complete rope assembly characteristics and associated tolerances are to be documented.

7.7 Identification

7.7.1 Each wire rope assembly is to be marked at each end with the letters LR and the Certificate Number.

7.8 Certification

7.8.1 A certificate is to be issued for each rope assembly by LR. The following is to be included in the Certificate:

- Purchaser's name and order number.
- Description of order, including wire rope diameter and construction.
- Tested minimum breaking load.
- Design Appraisal Document Number.
- Socket inspection certificate references.
- Individual wire certificate references.
- Sheathing report references.

■ *Section 8* Chains

8.1 Chain grades

8.1.1 Chains to be offshore Grades R3, R3S, R4, R4S or R5 (*see Pt 3, Ch 10, 8.1 Chain grades 8.1.2*) and are to comply with *Ch 10, 3 Stud link mooring chain cables* and *Ch 10, 4 Studless mooring chain cables* of the Rules for Materials, as applicable. Acceptance of other grades will be subject to special consideration.

8.1.2 Acceptability of chains of material grade R5 will be given special consideration and be subject to satisfactory qualification testing of the chain for validation of the API RP 2SK tension-tension fatigue curve by the manufacturer.

8.1.3 The maximum allowable tensile yield strength for the grade considered is to be agreed with the purchaser and documented for each project.

When the minimum tensile yield strength specified in *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials is exceeded by more than 3 per cent of the specified minimum value for the grade considered, the purchaser is to be notified and the actual yield strength from tests to be reported.

8.2 Corrosion and wear

8.2.1 A size margin over and above the minimum chain size required to satisfy Rule factor of safety requirements is to be included to allow for the corrosion and wear which can occur over the intended service life of the anchor chain or associated component. The minimum margins shown in *Pt 3, Ch 10, 8.2 Corrosion and wear 8.2.1* are recommended.

Note: These rates are minimum recommendations. The actual rate of corrosion should be monitored during successive periodical surveys to access the necessity to replace the chains in case accelerated corrosion or excessive pitting is observed. It should be noted that in tropical and subtropical regions as well as some coastal areas much greater rates of corrosion (sometimes exceeding twice these rates through localised pitting) have been observed. The Owner is to specify their corrosion protection strategy and may specify a larger minimum rate of corrosion for specific projects, taking due account of the region of operation of the unit.

Table 10.8.1 Chain size corrosion and wear margins

Region of anchor chain	Margin (mm per year service life, on chain diameter)
Splash zone	0,3
Catenary	0,2
Touch down zone and sea bed	0,4

NOTE

Additional margins greater than those indicated in the Table may be required where chains are subjected to high wear rates.

8.3 Additional specific requirements

8.3.1 The purchaser is to specify the project specific material, manufacturing and testing requirements where these complement, exceed or are more onerous than those of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials (e.g. chain length and tolerances, maximum yield strength, coating, reference link identification).

These shall be reported and agreed with LR.

8.3.2 A datasheet is to summarise all characteristics of each chain segment as necessary to ensure satisfactory deployment of the chain within the Positional Mooring System and to support the in service inspection, repair and maintenance plan.

■ *Section 9*
Fibre ropes

9.1 General

9.1.1 This Section gives requirements for fibre ropes part of loose or semi-taut catenary mooring lines of positional mooring systems of offshore units.

The use of fibre rope is confined to the suspended immersed part of the catenary system.

Generally chain or wire rope or special connectors shall be fitted in parts of the anchor leg subject to contact with sea bed or in the vicinity of the attachment point of the mooring line to the offshore unit.

Note that the requirements *Pt 3, Ch 13, 5 Mooring hawsers and load monitoring*, only apply to hawsers used in temporary berthing of shuttle tankers or ship to CALM buoys operated, inspected and maintained in accordance with OCIMF recommendations. Fibre ropes used as hawsers in the long term mooring of Offshore Units to CALM buoy or SALM system shall generally comply with the requirements of this *Pt 3, Ch 10 Positional Mooring Systems* and specific requirements on fibre ropes from this section. They shall be designed for the site specific loading (strength and fatigue) with sufficient redundancy (i.e. considering one line failed case).

9.1.2 Acceptance of fibre ropes will be based on:

- submission of complete design, manufacturing and installation documentations for design appraisal by LR.
- compliance with API RP 2SM Design, Manufacture, Installation, and Maintenance of Synthetic Fibre Ropes for Offshore Mooring as applicable to the specific rope design, field deployment and service.
- compliance with the requirements of this section and the requirement of LR Rules for Materials (especially *Ch 10 Equipment for Mooring and Anchoring*) where this is more specific or onerous as applicable to the specific rope design, field deployment and service.
- qualification testing as agreed with LR (and generally in line with API RP 2SM).
- manufacturing and production testing under LR Survey and certification by LR.

9.2 Design aspects

9.2.1 Fibre ropes and associated fittings are to be of an approved design. The following information to be submitted:

(a) Specifications:

- Rope purchaser’s functional and manufacturing specifications.
- Rope design specification.
- Rope manufacturing and testing specification.

(b) Plans:

- Rope assembly, spool piece and other fittings (pins, shackles, connectors etc.).

(c) Calculations:

- Strength and fatigue of rope and fittings.

(d) Rope particulars:

- Fibre type.
- Diameter of rope.
- Length at specified reference tension.
- Construction.
- Weight in air and water.
- Sheath or jacket type and characteristics.
- Terminations.
- Bend limiters.

(e) Rope properties:

- Minimum breaking strength.
- Mean breaking load of rope and coefficient of variation, from tests.
- Axial stiffness values (to cover upper and lower bounds of stiffness).
- Fatigue data (tension-tension and compression).
- Creep.
- Hysteresis.
- Torque/twist.
- Resistance to chemical attack in an offshore environment.
- Long-term degradation.
- Inspection, maintenance and repair plan.

9.2.2 Factors of safety for fibre rope are to be a minimum of 20 per cent higher than the levels given in *Pt 3, Ch 10, 6 Anchor lines* for chain and wire rope materials.

Factor of safety = $\dfrac{\text{Minimum breaking strength}}{\text{Maximum tension}}$

A reduction factor will require to be applied to the standard designated Minimum Breaking Strength, where the test database for the rope type is statistically small.

This does not generally apply to polyester fibre ropes for which sufficient test data, manufacturing and service experience can be documented.

9.2.3 Fibre ropes shall remain within the water column under all service conditions and not touch the sea bed in any intact or damaged condition.

9.2.4 Fibre ropes shall be kept sufficiently far below the waterline, and below the connection point on the unit, to avoid any possibility of contact damage, degradation by UV exposure, excessive marine growth developing on the sheathing, detrimental intermittent soaking/drying etc.

9.3 Manufacture

9.3.1 Fibre ropes are to be manufactured at a works approved by LR.

9.3.2 Ropes and fittings will be subject to LR survey during manufacture and testing.

9.3.3 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR Surveyors.

9.3.4 The ropes and fittings are to be manufactured in accordance with the approved design, standards and procedures.

9.3.5 *See also* requirement of *Ch 10, 7 Fibre ropes* of the Rules for Materials.

9.4 Additional specific requirements

9.4.1 The purchaser is to specify the project specific material, manufacturing and testing requirements where these complement, exceed or are more onerous than those of this *Pt 3, Ch 10, 9 Fibre ropes* , *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials (e.g. chain length and tolerances, maximum yield strength, coating, reference link identification etc.) or API RP 2SM. These shall be reported and agreed with LR.

9.4.2 A datasheet is to summarise all characteristics of each fibre rope segment as necessary to ensure satisfactory deployment of the rope within the Positional Mooring System and to support the in service inspection, repair and maintenance plan.

■ *Section 10* Fairleads and cable stoppers

10.1 General requirements

10.1.1 Fairleads and stoppers are to be designed to permit free movement of the anchor line in all mooring configurations and designed to prevent excessive bending and wear of the anchor lines. The hardness of fairleads and chain stoppers where in contact with the anchor line should be softer than the anchor line. In general, the anchor line should not be in contact with any welds but where this is not possible the welds are to be ground flush and are to be softer than the anchor line.

10.1.2 The minimum operating range of the fairlead to be considered in conjunction with the design load is shown in Fig. 10.11.1.

10.1.3 Fairleads and stoppers and their supporting structures are to be designed for a mooring line pull load equivalent to:

- the mooring line maximum design load as defined from intact mooring load case (as defined in *Pt 3, Ch 10, 4 Design aspects*, *Pt 3, Ch 10, 5 Design analysis* and *Pt 3, Ch 10, 6 Anchor lines*) for a range of mooring line pull angles as substantiated by analyses (including a 5 degrees contingency)

and

- the maximum break strength of the main component (steel wire rope, chain or fibre rope), in “as new” condition, directly acting on or closest in the load path to the structure under consideration. The range of mooring line pull direction shall match that reported in Section *Pt 3, Ch 10, 10.1 General requirements*. The maximum break load is generally to be based on expected maximum break strength plus two standard deviations (when sufficiently documented from manufacturer's test data), otherwise not less than 110% of the nominal minimum break strength of the mooring line component.

  For this case, special consideration will be given to acceptance of local yielding and deformation of fairleads and stoppers when it can be shown:

  The support structure to the fairlead or stopper satisfies the requirement of*Pt 4, Ch 6, 1.1 General* .

  The deformation does prevent repair or replacement but does not otherwise affect the integrity of the overall hull, does not lead to progressive collapse, has no substantial consequences, such as, loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking.

  The fairlead or stopper can be readily inspected and can be repaired or replaced offshore. Specific inspections, repair or replacement procedures are documented in IMR Manual and sparing policy ensures spares are readily and locally available.

The maximum permissible stresses for the design cases given in this sub-Section are to be in accordance with*Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

10.1.4 Fairleads, stoppers and support structures shall also be assessed for the mooring line load from damaged mooring load case (as defined in Section *Pt 3, Ch 10, 4 Design aspects*,*Pt 3, Ch 10, 5 Design analysis* and *Pt 3, Ch 10, 6 Anchor lines*) for a range of mooring line pull angles as substantiated by analyses (including a 5 degrees contingency) The maximum permissible stresses for the design cases given in this sub-Section are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

10.1.5 Materials and steel grades are generally to comply with the requirements given in *Pt 4, Ch 2 Materials* for primary structures.

10.1.6 Chain cable fairleads are to have a minimum of five pockets.

10.1.7 Wire rope fairleads are generally to have a minimum diameter of 16 times the wire rope diameter.

10.1.8 Special consideration will be given to permissible stresses where the chain is of downgraded quality. There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

10.1.9 For permanent mooring systems it is recommended that those lengths of the mooring lines which lie over a fairlead or other similar curved surface are not maintained for any extended period of time at the operating tension that would normally apply to the main part of the lines, but rather only for temporary line tension adjustments that might be necessary for inspection, maintenance or repair. It is generally preferable to have a suitably designed stopper holding the mooring line load outboard of the fairlead. Where applicable the long term detrimental effect of the wheel type fairlead action on the mooring line should be assessed and documented. Note: API RP 2SK etc.

10.1.10 Hawse pipes, guide pipes, or bend shoes and fairleads etc. used in the mooring system are to have adequate strength for the imposed loads. Detailed assessment of the interaction between these devices and mooring line chain or cable shall be documented. The design should take into account the inter-link locking mechanism and the loads required to align the device with the cable through swivel or articulation as well as the intermittent contact interaction in the area where the mooring line separates from the support or bearing surfaces. Hawse pipes or guide pipes when located inside tanks are to also be designed for sloshing forces). Close fit between mooring line and mooring line bearing arrangement shall be designed to minimise detrimental bending and stress concentrations in both mooring line and the mooring line bearing arrangement. The design shall ensure the bearing arrangement and mooring line bearing on it can be inspected and replaced in service.

10.1.11 Sensitivity of the design to the actual long term performance of the bearings are to be considered.

10.1.12 The fairlead, stoppers and bending shoes shall be protected against corrosion and designed such that their performances are not affected by corrosion.

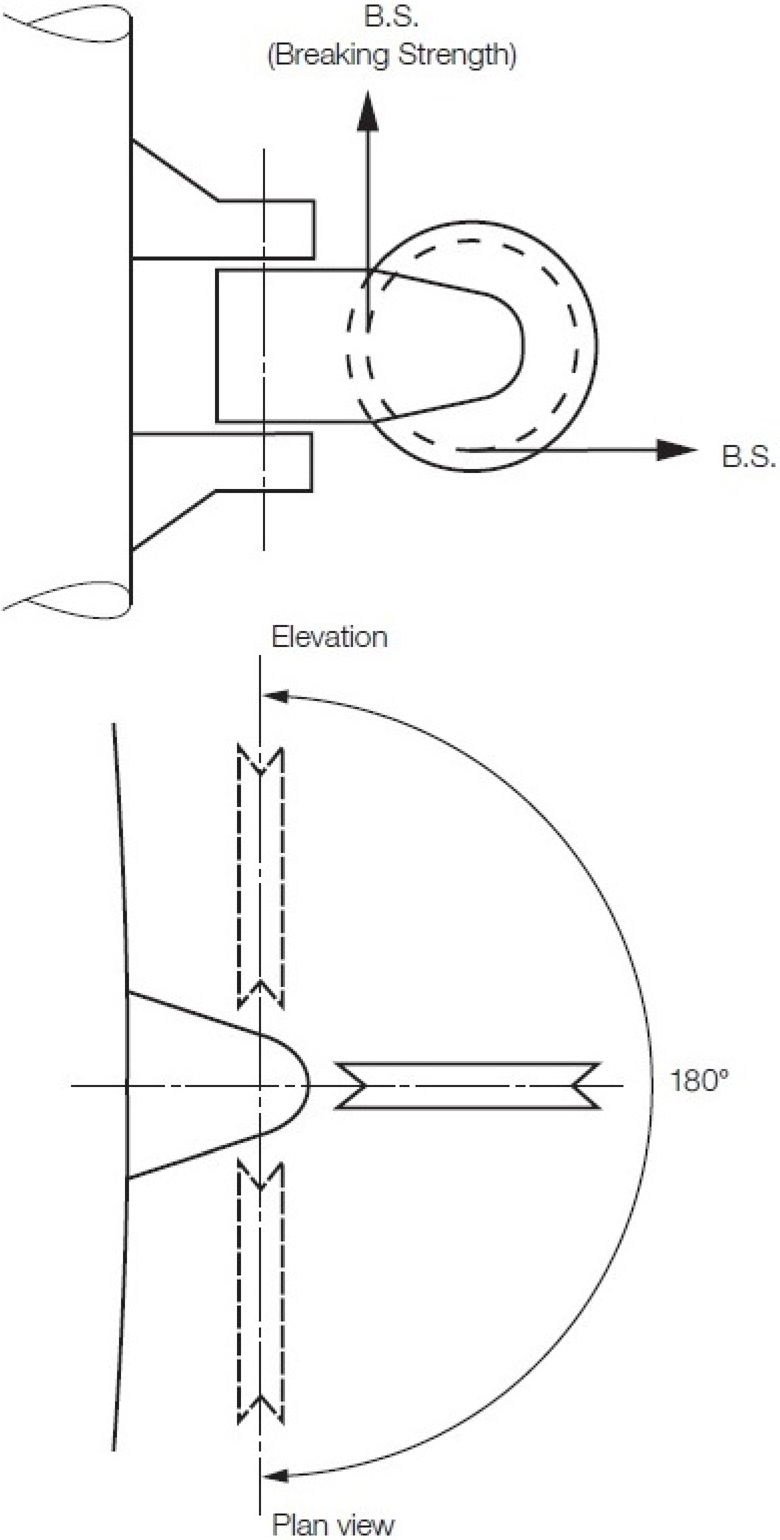


Figure 10.10.1 Minimum operating range of fairlead

■ Section 11
Anchor winches and windlasses

11.1 General

11.1.1 This Section applies to winches and windlasses designed actively to control anchor line tensions in-service, or to release anchor lines in an emergency.

11.1.2 Special consideration will be given to requirements for winches and windlasses for passive mooring systems, or permanent mooring systems.

11.1.3 Machinery items are to be constructed to recognised design Codes and Standards. The relevant requirements of *Pt 5 MAIN AND AUXILIARY MACHINERY*may be used as guidance for small and simple equipment, but, special analysis techniques such as finite element methods (or equivalent) are considered to be more appropriate.

11.1.4 Machinery items are to be installed and tested in accordance with the relevant requirements of *Pt 5 MAIN AND AUXILIARY MACHINERY*. For electrical and control equipment, *see Pt 3, Ch 10, 12 Electrical and control equipment*.

11.1.5 Along this Section the maximum break load refers to the maximum break strength (as new and based on expected maximum break strength plus two standard deviations) of the main component (steel wire rope, chain or fibre rope) directly acting on or closest in the load path to the structure under consideration and is generally not to be taken lower than 110% of the nominal minimum break strength of the component.

11.2 Materials

11.2.1 Materials are to comply with the Rules for Materials. Alternatively, materials which comply with national or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials, or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

11.2.2 For the selection of material grades, individual components of anchor winches and windlasses are to be categorised as primary or secondary.

11.2.3 Components where the failure would result in the loss of a primary function of the winch or windlass are considered to be ‘primary components’, *see also Pt 3, Ch 10, 11.2 Materials*.

11.2.4 All other components where the failure would not result in the loss of a primary function of the winch or windlass are to be categorised as ‘secondary components’.

11.2.5 Primary components which are designed with an adequate degree of redundancy in their operation will be specially considered and may be categorised as secondary.

11.2.6 Material grades for all components are in general related to the thickness of the material, the structural category and the minimum design air temperature and are to be selected to provide adequate notch toughness.

11.2.7 Material grades for welded plate components are in general to comply with*Pt 4, Ch 2, 4 Steel grades* For thicker plates and/or lower design temperature the steel grades will be specially considered.

11.2.8 Material grades for components which are not subject to welding will be specially considered.

11.2.9 Castings and forgings are to comply with *Ch 4 Steel Castings*and *Ch 5 Steel Forgings* of the Rules for Materials respectively and the requirements for notch toughness in relation to the design air temperature will be specially considered.

11.2.10 Non-ductile materials are not to be used for torque transmitting items or for those elements subject to tensile/bending stresses.

11.2.11 Spheroid graphite iron castings are to comply with *Ch 7, 3 Spheroidal or nodular graphite iron castings* of the Rules for Materials, Grades 370/17 or 400/12, or to an equivalent National Standard.

11.2.12 The use of grey iron castings will be subject to special consideration. Where approved, they are to comply with the requirements of *Ch 7, 2 Grey iron castings*of the Rules for Materials. This material is not to be used for gear components.

11.2.13 Brake lining materials are to be compatible with operating environmental conditions.

11.3 Brakes

11.3.1 Each anchor winch or windlass is required to have one primary braking system and one secondary braking system. The two systems are to operate independently. The requirements of *Pt 3, Ch 10, 11.5 Winch/windlass performance* are to be complied with.

11.3.2 The braking action of the motor unit may be used for secondary braking purposes where the design is suitable.

11.3.3 A residual braking force of at least 50 per cent of the maximum braking force required by *Pt 3, Ch 10, 11.5 Winch/windlass performance* is to be immediately available and automatically applied in the event of a power failure.

11.4 Stoppers

11.4.1 If the winch motor is to be used as a secondary brake then a stopper is to be provided to take the anchor line load during maintenance of the primary brake.

11.4.2 The stopper may be one of two different types: a pawl stopper fitted at the cable lifter/drum shaft, or a stopper acting directly on the anchor line.

11.4.3 Where the stopper acts directly on the cable, its design is to be such that the cable will not be damaged by the stopper at a load equivalent to the nominal minimum breaking strength of the cable (as new).

11.4.4 *See also Pt 3, Ch 10, 12.4 Controls of winch and windlass systems 12.4.11* and *Pt 3, Ch 10, 12.4 Controls of winch and windlass systems 12.4.12* , for stopper control station requirements, and *Pt 3, Ch 10, 12.4 Controls of winch and windlass systems 12.4.6* , for emergency release of stoppers.

11.5 Winch/windlass performance

11.5.1 The primary brake is required to hold a static load equal to the maximum break strength of the anchor line (at the intended outer working layer of wire rope on storage drum winches). The static load capacity of the primary brake can be reduced to 80 per cent of the nominal minimum break load of the mooring line (as new) when a stopper, capable of holding maximum breaking strength of the line, is fitted.

11.5.2 The secondary brake is required to hold a static load equal to 50 per cent of the nominal minimum breaking strength of the anchor line (as new).

11.5.3 For passive or permanent positional mooring systems the primary brake is required to hold a static load equal to 150 per cent of the winch/windlass capacity, when isolated from operational/survival mooring line loads using a stopper. A secondary brake is not required in this case.

11.5.4 The anchor winch or windlass is to have adequate dynamic braking capability. The two brake systems in joint operation are to be capable of fully controlling without overheating, the anchor lines during:

- all anchor handling operations;
- adjustment of anchor line tensions. (This is particularly relevant where the mooring system has been designed and sized on the basis of active adjustment of anchor lines in extreme conditions, to minimise line tensions.)

11.5.5 *See also Pt 3, Ch 10, 12.4 Controls of winch and windlass systems 12.4.1* for control of winches, windlasses, stoppers and pawls, for brake fail-safe requirements and standby power for operation of brakes and release of stoppers in the event of a failure of normal power supply.

11.5.6 Means are to be provided to enable the anchor lines to be released from the unit after loss of main power.

11.5.7 On Offshore Mobile Units, the pulling force of the winches or windlasses is to be sufficient to carry out anchor pre-loading on location, to the necessary level. A minimum low-speed pull equal to 40 per cent of the anchor line nominal minimum breaking strength is recommended.

11.6 Strength

11.6.1 Design load cases for the winch or windlass assembly and the stopper, when fitted, are given in *Pt 3, Ch 10, 11.6 Strength 11.6.1* . The associated maximum allowable stresses are to be based on the factors of safety given in *Pt 3, Ch 10, 11.7 Testing 11.7.2* .

Table 10.11.1 Design load cases

Load case	Condition	Anchor line load
1	Winch braked	Maximum break strength, *see* Note
2	Stopper engaged	Maximum break strength
3	Winch pulling	40% of nominal minimum break load (as new) or specified duty pull if greater
Note: Where a stopper is fitted, the anchor line load in Case 1 may be taken as the brake slipping load, but is not to be less than 80% of the nominal minimum break strength of the anchor line (in as new conditions).		

11.7 Testing

11.7.1 Tests are to be carried out at the manufacturer’s works in the presence of the Surveyor, on at least one of the winches or windlasses out of the total outfit for the unit. The tests to be carried out are given in *Pt 3, Ch 10, 11.7 Testing 11.7.2* . Alternatively, where a prototype winch has been suitably tested, consideration will be given to the acceptance of these results.

11.7.2 The residual braking capability is to be verified in accordance with *Pt 3, Ch 10, 11.5 Winch/windlass performance*.

Table 10.11.2 Load case factors of safety

Stress	Load case	
	1 and 2	3
	Factor of safety	
Shear	1,89	2,5
Tension, compression, bending	1,25	1,67
Combined	1,11	1,43

NOTES

1. Factors of safety relate to tensile yield stress.

2. Combined stress = $\sqrt{\sigma_X^2 + \sigma_Y^2 - \sigma_X \sigma_Y + 3\tau^2}$

Where σX and σY are the combined axial and bending stresses in the X and Y directions respectively and τ is the combined shear stress due to torsion and/or bending in the X–Y plane.

Table 10.11.3 Winch/windlass tests

Test	Test load
Static brake – Primary	Maximum break strength (or 80% of nominal minimum break strength of mooring line (as new) where stopper is fitted,*see* 11.5.1)
Static brake – Secondary	50% anchor line nominal minimum break strength of mooring line (as new)
Stopper (where fitted)	Maximum break strength
Motor stall test	Specified stall load

11.7.3 Each winch or windlass is to be tested on board the vessel in the presence of the Surveyor, to demonstrate that all main aspects including dynamic brakes function satisfactorily.

A static overload test to 125% of the winch´s Nominal Load (defined as the chain or rope tension that the winch is able to maintain continuously when hauling at nominal speed, measured either at the cable-lifter exit, or at the rope exit of the first layer in the case of a wire-drum shall be considered in addition to functional testing carried out on board.. Further guidance on testing to be carried out can be gained from BS 7464:1991/ISO 9089.

The proposed test programme is to be submitted.

11.7.4 Mooring winches and windlasses are to be regularly tested during service as part of the inspection maintenance and repair plan. Note that winches used in support of inspection, maintenance and repair plan (e.g. to shift chain links in the stopper during inspections) should be maintained as well as winches used in support of mooring line failure or loss of station keeping capability. The failure response procedure is to be kept in good working condition and regularly tested.

11.8 Type approval

11.8.1 Winches or windlasses may be Type Approved in accordance with LR's *Type Approval Scheme*. Where this Type Approval is obtained, the requirements of *Pt 3, Ch 10, 11.7 Testing* may not be applicable.

■ *Section 12*
Electrical and control equipment

12.1 General

12.1.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of *Pt 6, Ch 2 Electrical Engineering*

12.1.2 Control, alarm and safety systems are to be designed, constructed and installed in accordance with the relevant requirements of*Pt 6, Ch 1 Control Engineering Systems*, together with the requirements of 12.2 to 12.4.

12.1.3 Reference should be made to the general requirements of*Pt 3, Ch 10, 13 Thruster-assisted positional mooring* for thruster-assisted positional mooring systems.

12.2 Controls, indications and alarms

12.2.1 Adequate control, indication and alarm systems are to be provided to ensure satisfactory operation of the positional mooring system.

12.2.2 A suitable central control station is to be provided.

12.2.3 Where additional local control stations are provided, means of direct communication between the local and central control stations are to be arranged.

12.2.4 Indication of the following, as applicable, is to be provided at the central control station, and where local control is provided, at the local control station:

(a) Position of unit.
(b) Heading of unit.
(c) Anchor line tensions.
(d) Wind speed and direction.
(e) Offloading tanker status:

- position.
- heading.
- hawser tension.
- offloading hose connections status.

12.2.5 Alarms are to be provided for the following fault conditions, as applicable:

(a) Deviation from positional limits.
(b) Deviation from heading limits.
(c) Deviation from anchor line tension limits (high and low).

(d) Gyro compass fault.
(e) Position reference system fault.
(f) Wind speed and direction indicator fault.
(g) Offloading tanker deviation from attached limits.
(h) Control computer system fault.
(i) Turret/unit relative heading limit exceedence.

12.3 Control aspects – Disconnectable mooring systems

12.3.1 This sub-Section is applicable to units or ships which are disconnectable to avoid hazards or severe storm conditions.

12.3.2 Power, control and thruster systems and other systems necessary for the correct functioning of the positional system are to be provided and configured such that a fault in any active component will not result in a loss of position.

12.3.3 At least two automatic control systems are to be provided and arranged to operate independently.

12.3.4 Adequate controls are to be provided at the control station for satisfactory operation of the connect/disconnect mechanism.

12.3.5 Hydraulic and electrical systems are to be served by two means of power supply. Failure of the main supply is to activate an alarm.

12.3.6 Where the mooring system is designed on the basis of the unit or ship disconnecting at limiting environmental levels below the 100-year extreme case required by 4.3, means are to be provided to enable the rapid release of the unit or ship as applicable from the mooring system in an emergency. The quick-disconnect system is to be based on single operation at the control station, and may be independent of the normal control system.

12.3.7 Suitable fail-safe measures are to be provided to prevent inappropriate or inadvertent disconnection of the mooring system.

12.3.8 The reconnection of a disconnectable unit or ship is to be to the satisfaction of LR Surveyors.

12.4 Controls of winch and windlass systems

12.4.1 This sub-Section is applicable to mooring systems incorporating winches, windlasses, etc., which are used to actively control and adjust anchor line tensions in-service, or to release anchor lines in an emergency.

12.4.2 Adequate controls are to be provided at the local control station for satisfactory operation of the winch(es).

12.4.3 The braking system is to be arranged so that the brakes, when applied, are not released in the event of a failure of the normal power supply.

12.4.4 Standby power is to be provided to enable winch brakes to be released within 15 seconds in an emergency. The release arrangements are to be operable locally at each winch and from the central control position, and are to be such that the entire anchor line can be lowered in a controlled manner.

12.4.5 The standby power is to be such that during lowering of the anchor line it is possible to apply the brakes once and then release them again in a controlled manner.

12.4.6 Standby power is to be provided so that any anchor line stoppers or pawl mechanisms may be released from either the local or central control stations up to a line tension equal to the minimum rated break strength of the anchor line. These mechanisms are to be capable of release at the maximum angles of heel and trim under the damage stability and flooding conditions for which the unit is designed.

12.4.7 At least one position reference system and one gyrocompass or equivalent is to be provided, when applicable, to ensure the specified area of operation and heading deviation can be effectively monitored.

12.4.8 Position reference systems are to incorporate suitable position measurement techniques which may be by means of acoustic devices, radio, radar, taut wire, riser angle, gangway extension and angle or other acceptable means, depending on the service conditions for which the unit is intended.

12.4.9 A vertical reference sensor is to be provided, if applicable, to measure the pitch and roll of the unit.

12.4.10 Means are to be provided to ascertain the wind speed and direction acting on the unit.

12.4.11 The operation of winches, windlasses and associated brakes, chain stoppers and pawls is to be controlled locally from weather protected control stations which provide good visibility of the equipment and associated anchor handling operations.

12.4.12 A central control station, which may be located on the bridge or a separate manned control room, is to be provided from which brakes, chain stoppers and pawls can be remotely released.

12.4.13 For each anchor winch the respective local control station is to be provided with a means of indicating the following:

(a) Line tension.
(b) Length of line paid out.
(c) Line speed.

12.4.14 The indication required by 12.4.13(a), and (b), is to be repeated to the central control station and in addition a means of indicating the following is to be provided at this position:

(a) Mooring patterns and anchor line catenaries.
(b) Status of winch operation.
(c) ition and heading, *see also* 12.4.7.
(d) Gangway angle and extension, when applicable.
(e) Riser angle, when applicable.
(f) Wind speed and direction, *see also* 12.4.10.

12.4.15 Means of voice communication are to be provided between the central control station, each local control station and anchor handling vessels, when applicable.

12.4.16 Alarms are to be provided at the local and central control stations for the following fault conditions:

(a) Excessive line tension.
(b) Loss of line tension.
(c) Excessive gangway angle and extension, when applicable.
(d) Excessive riser angle, when applicable.

12.4.17 Alarms are to be provided adjacent to the winches and windlasses to warn personnel prior to and during any remote operation.

12.4.18 Alarms are to be provided at the central control station for the following fault conditions:

(a) When the unit deviates from its predetermined area of operation.
(b) When the unit deviates from its predetermined heading limits.

These alarms are to be adjustable but should not exceed specified limits. Arrangements are to be provided to fix and identify their set points.

■ *Section 13*
Thruster-assisted positional mooring

13.1 General

13.1.1 Where the positional mooring system is assisted by thrusters, as defined in *Pt 3, Ch 10, 4 Design aspects*, units complying with the requirements of this Section together with the requirements in *Pt 3, Ch 10, 13 Thruster-assisted positional mooring* will be eligible for one of the following class notations as specified in 1.2:

TA(1) *See* 13.1.
TA(2) *See* 13.2.
TA(3) *See* 13.3.

13.1.2 Machinery items are to be constructed, installed and tested in accordance with the relevant requirements of *Pt 5 MAIN AND AUXILIARY MACHINERY*, together with the requirements of 13.2 and Section 14.

13.2 Thrust units

13.2.1 Thruster installations are to be designed to minimise potential interference with other thrusters, sensors, hull or other surfaces which could be encountered in the service for which the unit is intended.

13.2.2 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.

13.2.3 Steerable thrusters and thrusters having variable pitch propellers are to be provided with two independent supplies of motive power to the pitch and direction actuating mechanisms.

13.2.4 Each thruster unit is to be provided with a high power alarm. The setting of this alarm is to be adjustable and below the maximum thruster output.

13.2.5 The response and repeatability of thrusters to changes in propeller pitch or propeller speed/direction of rotation are to be suitable for maintaining the area of operation and the heading deviation specified.

13.2.6 The thrust unit housing is to be tested at a hydraulic pressure of not less than 1,5 times the service immersion head of water or 1,5 bar (1,5 kgf/cm_2), whichever is the greater.

13.3 Electrical equipment

13.3.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of*Pt 6, Ch 2 Electrical Engineering* together with the requirements of 13.3.3 to 13.3.8, and the relevant requirements of *Pt 3, Ch 10, 14 Thruster-assist class notation requirements*.

13.3.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, defined in *Pt 6, Ch 2, 15 Navigation and manoeuvring systems* are to be complied with.

13.3.3 The total generating capacity is to be in accordance with*Pt 3, Ch 10, 14.1 Notation TA(1)*, *Pt 3, Ch 10, 14.2 Notation TA(2)* and *Pt 3, Ch 10, 14.3 Notation TA(3)*, as applicable.

13.3.4 Where the electrical power requirements are supplied by one generator set, on loss of power there is to be provision for automatic starting and connection to the switchboard of a standby set and automatic restarting of essential auxiliary services. For other requirements relevant to particular thruster-assisted class notations, *see Pt 3, Ch 10, 14 Thruster-assist class notation requirements*.

13.3.5 An alarm is to be initiated at the thruster-assisted positioning control station(s) when the total electrical load of all operating thruster units exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50 and 100 per cent of the full load capacity, having regard to the number of electrical generators in service.

13.3.6 The number and ratings of power transformers are to be sufficient to ensure full load operation of the thruster-assisted positioning system even when one transformer is out of service. This does not require duplication of a transformer provided as part of a transformer/silicon controlled rectifier (SCR) drive unit.

13.3.7 Thruster auxiliaries, control computers, reference systems and environmental sensors are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practical and without the use of common feeders, transformers, converters, protective devices or control circuits.

13.3.8 Where the auxiliary services and positioning mooring thrusters are supplied from a common source, the following requirements are to be complied with:

(a) The voltage regulation and current-sharing requirements defined in*Pt 6, Ch 2, 8 Protection from electric arc hazards within electrical equipment*are to be maintained over the full range of power factors that may occur in service.
(b) Where SCR converters are used to feed the thruster motors, and the instantaneous value of the line-to-line voltage wave-form on the a.c. auxiliary system busbars deviates by more than 10 per cent of $\sqrt{2}$ times the r.m.s. voltage from the instantaneous value of the fundamental harmonic, the essential auxiliary services are to be capable of withstanding the additional temperature rise due to the harmonic distortion. Control, alarm and safety equipment is to operate satisfactorily with the maximum supply system wave-form distortion, or be provided with suitably filtered/converted supplies.
(c) When the control system incorporates volatile memory it is to be supplied via uninterruptible power supplies provision for automatic starting and connection to the (UPS), *see also Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements*.

13.4 Control engineering systems – Additional requirements

13.4.1 The control engineering systems are to be designed in accordance with the relevant requirements of *Pt 3, Ch 10, 12 Electrical and control equipment* together with the additional requirements of 12.4.2 to 12.4.3 and the relevant requirements of *Pt 3, Ch 10, 14 Thruster-assist class notation requirements*.

13.4.2 Indication of the following is to be provided at each station from which it is possible to control the thruster-assisted positioning system, as applicable:

- The heading and location of the vessel relative to the desired reference point or course.
- Vectorial thrust output, individual and total.
- Operational status of position reference systems and environmental sensors.
- Environmental conditions, e.g., wind speed and direction.
- Availability status of standby thruster units.

13.4.3 Alarms are to be provided for the following fault conditions where applicable:

- When the unit deviates from its predetermined area of operation.
- When the unit deviates from its predetermined heading limits.
- Position reference system fault (for each reference system).
- Gyrocompass fault.
- Vertical reference sensor fault.
- Wind sensor fault.
- Taut wire excursion limit.
- Automatic changeover to a standby position reference system or environmental sensor.
- Control computer system fault.
- Automatic changeover to a standby control computer system, *see Pt 3, Ch 10, 14.3 Notation TA(3)*

13.4.4 Suitable processing and comparative techniques are to be provided to validate the control system inputs from position and other sensors, to ensure the optimum performance of the thruster-assisted mooring system.

13.4.5 Abnormal signal errors revealed by the validity checks required by 13.4.4 are to operate alarms.

13.4.6 The control system for thruster-assisted positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

13.4.7 Automatic controls are to be provided to maintain the desired heading of the unit.

13.4.8 The deviation from the desired heading is to be adjustable, but is not to exceed the specified limits. Arrangements are to be provided to fix and identify the set point for the desired heading.

13.4.9 Sufficient instrumentation is to be fitted at the central control station to ensure effective control and indicate that the system is functioning correctly, *see* 13.4.2.

■ *Section 14*
Thruster-assist class notation requirements

14.1 Notation TA(1)

14.1.1 For assignment of the notation **TA (1)**, in accordance with Section 4, the applicable requirements of *Pt 3, Ch 10, 12 Electrical and control equipment* and *Pt 3, Ch 10, 13 Thruster-assisted positional mooring* together with *Pt 3, Ch 10, 14.1 Notation TA(1) 14.1.2* to *Pt 3, Ch 10, 14.1 Notation TA(1) 14.1.2* are to be complied with.

14.1.2 Centralised automated manual control of the thrusters is to be provided to supplement the position mooring system. The manual control system is to provide output signals to the thrusters via the manual controller to change the speed, pitch and azimuth angle, as applicable, as indicated at the central control station, *see Pt 3, Ch 10, 13.2 Thrust units*.

14.1.3 For electrically driven thruster systems, the total generating capacity of the electrical system is to be not less than the maximum dynamic positioning load together with the maximum auxiliary load. This may be achieved by parallel operation of two or more generating sets, provided the requirements of *Pt 6, Ch 2, 2.2 Number and rating of generators and converting equipment* are complied with.

14.2 Notation TA(2)

14.2.1 For assignment of the notation **TA (2)**, in accordance with *Pt 3, Ch 10, 4 Design aspects*, the applicable requirements of *Pt 3, Ch 10, 12 Electrical and control equipment*and *Pt 3, Ch 10, 13 Thruster-assisted positional mooring* together with 14.2.2 to 14.2.8 are to be complied with.

14.2.2 Automatic and manual control systems are to be provided to supplement the positional mooring systems and arranged to operate independently so that failure in one system will not render the other system inoperative, *see also* 14.1.2 for manual control.

14.2.3 The automatic control system is to utilise automatic inputs from the position reference system, the environmental sensors and line tensions, and automatically provide output signals to the thrusters to change the speed, pitch and azimuth angle, as applicable, such that the line tensions are optimised.

14.2.4 In the event of a failure of a reference or environmental sensor, the control systems are to continue to operate on signals from the remaining sensors without manual intervention.

14.2.5 In the event of line failure or failure of the most effective thruster, the unit is to be capable of maintaining its predetermined area of operation and desired heading in the environmental conditions for which the unit is designed and/or classed.

14.2.6 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that the anchor line tensions and position/heading deviations remain within acceptable limits. In the event of a possible hazardous condition arising as a result of the consequence analysis an alarm is to be initiated at the central control station.

14.2.7 The area of operation is to be adjustable, but is not to exceed the specified limits, which are to be based on a percentage of water depth, or if applicable a defined absolute surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.

14.2.8 For electrically driven thruster systems, the following requirements are to be complied with:

(a) Generating capacity, as defined in 14.1.3.
(b) With one generating set out of action, the capacity of maximum positioning load with the most effective thruster inoperative together with the essential services defined by Pt 6, Ch 2,1.5.
(c) Where generating sets are arranged to operate in parallel, the supplies to essential services are to be protected by the tripping of non-essential loads as required by *Pt 6, Ch 2, 6.9 Load management* and additionally, on loss of a running generator, a reduction in thrust demand may be accepted provided the arrangements are such that a sufficient level of dynamic position capability is retained to permit the three degrees of manoeuvrability of the unit.
(d) Indication of absorbed electrical power and available on-line generating capacity is to be provided at the main thruster-assisted positioning control station, *see* 14.4.1.
(e) Means are to be provided to prevent starting of thruster motors until sufficient generating capacity is available.

14.3 Notation TA(3)

14.3.1 For assignment of the notation **TA (3)**, in accordance with *Pt 3, Ch 10, 4 Design aspects*, the applicable requirements of *Pt 3, Ch 10, 12 Electrical and control equipment* and *Pt 3, Ch 10, 13 Thruster-assisted positional mooring*, together with 14.2.3 to 14.2.8 and 14.3.2 to 14.3.8, are to be complied with.

14.3.2 Two automatic control systems are to be provided and arranged to operate independently so that failure in one system will not render the other system inoperative.

14.3.3 In the event of failure of the working system the standby automatic control system is to be arranged to change over automatically without manual intervention and without any adverse effect on the vessel's station keeping capability. The automatic changeover is to initiate an alarm.

14.3.4 At least two position reference systems as defined by *Pt 3, Ch 10, 12.4 Controls of winch and windlass systems*, and two gyrocompasses or equivalent, are to be provided.

14.3.5 At least two of each of the sensors as required by 13.4.9 and 13.4.10 are to be provided.

14.3.6 When two voyage recording systems are deployed, their outputs are to be compared and an alarm raised when a significant difference occurs.

14.3.7 The arrangement is to be verified by means of a Failure Mode and Effects Analysis (FMEA). Such components may include, but not be restricted to, the following:

- Mooring systems.
- Prime movers, e.g., auxiliary engines.
- Generators and the excitation equipment.
- Switchgear.
- Pumps.
- Thrusters.
- Fans.
- Valves, where power-actuated.

14.3.8 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that position and heading deviation remain within acceptable limits. In the event of a possible hazardous condition being indicated from the consequence analysis, an alarm is to be initiated.

■ *Section 15* **Trials**

15.1 General

15.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be based on the approved test schedules list as required by *Pt 3, Ch 10, 1.4 Plans and data submission*.

15.1.2 The suitability of the positional mooring and/or thruster-assisted positional mooring system is to be demonstrated during sea trials, observing the following:

(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.

(b) Response of the system under a set of predetermined manoeuvres for changing:

- Location of area of operation;
- Heading of the unit.

(c) Automatic thruster control and line tension optimisation.

(d) Monitoring and consequence analyses.

(e) Simulation of line breakage and damping.

(f) Continuous operation of the thruster-assisted positional mooring system over a period of 4 to 6 hours.

15.1.3 Two copies of the test schedules, as required by *Pt 3, Ch 10, 1.4 Plans and data submission*, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the unit and the other submitted to LR.

15.1.4 Disconnect and reconnection of disconnectable positional mooring system are to be tested during the trial campaign.

15.1.5 The mooring line integrity monitoring system of the positional mooring system is to be tested during the trial campaign.

15.1.6 For turret moored offshore units, in so far as practical, the rotational resistance of the turret bearing arrangement is to be tested during the trial campaign.

■ *Section 1*
Rule application

1.1 General

1.1.1 Masts, derrick posts, crane pedestals and similar supporting structures to equipment are classification items, and the scantlings and arrangements are to comply with the additional requirements of this Chapter.

1.1.2 Certain lifting appliances on special purpose units which are considered an essential feature of the unit are to be included in the classification of the unit. Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements.

1.1.3 Where the lifting appliance is considered to be an essential feature of a classed unit, the special feature class notation **LA** will, in general, be mandatory.

1.1.4 Proposals to class lifting appliances on unclassed units will be specially considered.

1.2 Masts, derrick posts and crane pedestals

1.2.1 The scantlings of masts and derrick posts, intended to support derrick booms, and of crane pedestals are to comply with the requirements of LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code).

1.2.2 In addition to the information and plans requested in LR's LAME Code, the following details are to be submitted:

(a) Details of deckhouses or other supports for the masts, derrick posts or crane pedestals, together with details of the attachments to the hull structure.
(b) Details of any reinforcement or additional supporting material fitted to the hull structure in way of the mast, derrick post or crane pedestal.

1.2.3 Masts, derrick posts or crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into transverse or longitudinal bulkheads, or equivalent structure. Alternatively, the mast, derrick posts or crane pedestals may be carried into a deckhouse or equivalent structure, in which case the house is to be of substantial construction. Proposals for other support arrangements will be specially considered.

1.2.4 Deck plating and underdeck structure are to be reinforced under masts, derrick posts and crane pedestals. Where the deck is penetrated the deck plating is to be suitably increased locally.

1.2.5 The permissible stresses in the support structure are to be in accordance with*Pt 4, Ch 5, 2 Permissible stresses*

1.3 Lifting appliances

1.3.1 Offshore units fitted with lifting appliances built in accordance with LR's LAME Code in respect of structural and machinery requirements will be eligible to be assigned special features class notations as listed in Table 11.1.1. The notation will be retained so long as the appliances are found upon examination at the prescribed surveys to be maintained in accordance with LR's requirements.

Table 11.1.1 Special features class notations associated with lifting appliances

Cranes on offshore units	**PC**	Optional notation. Indicates that the unit's main deck cranes are included in class
Lifts	**PL**	Optional notation. Indicates that the unit's personnel lifts are included in class
Lifting appliances forming an essential feature of the unit e.g. Cranes on crane barges or units, lifting arrangements for diving on diving support units, etc.	**LA**	Mandatory notation. Indicates that the lifting appliance is included in class

1.4 Crane boom rests

1.4.1 With the crane boom in the stowed position, the structure of the crane boom support structure is to be designed for the maximum reaction forces in any operating condition, taking into account the maximum design environmental loadings and inertia forces due to motions of the unit.

1.4.2 The crane boom support structure is also to be verified in the emergency condition defined in *Pt 3, Ch 8, 1.4 Plant design characteristics*.

1.4.3 The permissible stresses in the crane boom support structure and the deck structure below are to be in accordance with *Pt 4, Ch 5, 2 Permissible stresses*.

1.5 Runway beams

1.5.1 Runway beams are to be designed and tested *in situ* in accordance with a recognised Standard and marked with the safe working load, *see also* Appendix A.

1.6 Lifting padeyes

1.6.1 Padeyes attached to the main structure which are to be used with a rated lifting appliance are to be proof tested after installation and marked with the safe working load (SWL). The proof load is not to be less than 1,5 x SWL.

1.6.2 Lifting lugs are to be permanently marked with the SWL, tested after installation and NDE to the Surveyor's satisfaction. In agreement with LR, testing and NDE of lifting lugs with SWL < 1 tonne may be by sampling, provided design calculations can demonstrate a factor of safety greater than 2.

1.7 Access gangways

1.7.1 Pedestals and similar structures supporting installed gangways used for access to adjacent fixed installations are classification items and the scantlings and arrangements are to comply with the general requirements for crane pedestals and support structure in *Pt 3, Ch 11, 1.2 Masts, derrick posts and crane pedestals*.

1.7.2 The gangway is to comply with the relevant statutory Regulations of the National Administration of the country in which the unit is registered and/or in which it is to operate and design calculations for the supporting structure are to be submitted.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to rigid and flexible risers, together with associated components, between the pipeline end manifold connection and the connection to the unit, *see Pt 3, Ch 12, 1.4 Scope*. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The requirements also apply to surface floating and suspended flexible loading hoses (as appropriate).

1.1.3 Submarine steel pipelines are to comply with the requirements contained in internationally recognised Codes and Standards.

1.1.4 The riser system will be considered for Classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

1.1.5 Risers may be arranged separately or in connected bundles comprising production risers together with other elements.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in *List of abbreviations*, to which reference should be made.

1.2.2 Offshore units connected to product riser systems which comply with the requirements of this Chapter will be eligible for the assignment of the special features class notation **PRS**.

1.2.3 The service limits on which approval of the riser system has been based are to be included in the Operations Manual, *see Pt 3, Ch 12, 2.5 Operations Manual*.

1.3 Definitions

1.3.1 The definitions in this Chapter are stated for Rule application only, and may not necessarily be valid in any other context.

1.3.2 **Riser system**. The riser together with its supports, component parts and ancillary systems such as corrosion protection, mid water arch, bend stiffeners, buoyancy modules, bend restrictors, bend stiffener latching mechanisms, etc.

1.3.3 **Riser**. A subsea flexible hose or rigid pipe leading down from the connection on the unit to a sea bed termination structure. Risers may have a variety of functions including liquid and gas export, water injection, chemical injection and controls, etc.

1.3.4 **Floating pipe**. A surface pipe between the single-point mooring or buoy and the ship manifold. The floating pipe is normally permanently attached to the single-point mooring.

1.3.5 **Riser support**. Any structural item used for connecting a part of the riser system to the unit.

1.3.6 **Riser components**. Valves, connections, etc., and similar apparatus incorporated in the riser system.

1.4 Scope

1.4.1 The following additional topics applicable to the special features class notation are covered by this Chapter:

- Welded steel risers.
- Flexible risers.
- Floating hoses.
- Pig traps.
- Valves, controls and fittings.
- Safety devices.
- Coverings and protection.
- Cathodic protection system.

1.4.2 Unless agreed otherwise with LR, the Rules consider the following as the main boundaries of the riser system:

- Any part of the riser system as defined in *Pt 3, Ch 12, 1.3 Definitions* from the sea bed termination to the first riser connector valves on the unit.
- The riser connector valves will normally be considered part of the offshore unit, unless agreed otherwise with LR.

1.5 Damage protection

1.5.1 Wherever possible, risers should be protected from collision damage either by suitable positioning within the unit or by protective structure provided for this purpose.

1.5.2 The risk of damage arising from impact loads should form an integral part of the riser assessment. The assessment should evaluate the risk and consequences to the installation of a release of hydrocarbon from the riser.

1.5.3 Design of the riser system should consider the avoidance of collisions between individual risers and anchor lines, etc., with the positioning system intact and in a single fault damaged state under the appropriate environmental conditions. Contact may be allowed in a single fault damaged state provided special external armoury is fitted to the risers in the interference regions, or where appropriate calculations and/or tests indicate that no damage to the risers will occur.

1.5.4 Risers designed to be capable of rapid release should not be damaged in the course of such release, nor should they inflict critical damage on other components.

1.6 Buoyancy elements

1.6.1 Where subsea buoyant vessels are provided as an inherent part of the riser system design, the requirements of *Pt 3, Ch 13, 2.3 Subsea buoyant vessels* are to be complied with.

1.6.2 The loss of buoyancy of any one element is not to affect adversely the integrity of the riser system.

1.7 Emergency shut-down (ESD) system

1.7.1 An ESD system is to be provided to riser systems in accordance with *Pt 7, Ch 1 Safety and Communication Systems*. This requirement is generally not applicable to conventional surface floating and suspended flexible loading hoses.

1.7.2 An ESD system philosophy should be developed for the installation based on appropriate hazard and safety assessments. Due consideration is to be given to the sequence of events in relation to overall installation safety.

1.7.3 To limit the quantity of flammable or toxic substances escaping in the event of damage to a riser, emergency shut-down valves are to be fitted. The valves and their control mechanisms should be positioned to offer the maximum protection to the unit in the event of damage.

1.7.4 Facilities are to be provided to make it possible at all times to isolate risers by means of valves.

1.7.5 Where appropriate, rapid disconnection of risers must be possible from at least one location. The assessment of how many locations to be provided, and where they should be situated, is to be based on the evaluation of various accident scenarios. Suitable fail-safe measures are to be provided to prevent inappropriate or inadvertent disconnection.

1.8 Recognised Codes and Standards

1.8.1 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for riser systems, as defined in*Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.8.2 The agreed Codes and Standards may be used for design, construction and installation, but the additional requirements stated in the Rules are to be complied with. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.8.3 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.8.4 Where National Administrations have specific requirements regarding riser systems, it is the responsibility of the Owner and Operators to comply with such Regulations.

1.9 Equipment categories

1.9.1 The approval and certification of riser systems are to be based on equipment categories agreed with LR.

1.9.2 Riser systems, including their associated components and valves, are to be divided into equipment Categories **1A**, **1B** and **II**, depending on their complexity of manufacture and their importance with regard to the safety of personnel and the installation and their possible effect on the environment.

1.9.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety, for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in Category **1A**.

II Equipment related to safety, which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excluding equipment in Category **1A** and **1B**.

1.9.4 A guide to equipment and categories is given in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*. A full list of equipment categories for the riser system is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.10 Equipment certification

1.10.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A:**

- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B:**

- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) **Category II:**

- Supplier's/manufacturer's works certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.10.2 All equipment recognised as being of importance for the safety of personnel and the riser system is to be documented by a data book.

1.11 Fabrication records

1.11.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:

- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.12 Site installation of riser systems

1.12.1 The installation of riser systems is to be controlled by LR in accordance with the following principles:

- All Category **1A** and **1B** equipment, when delivered to site, is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other documentation.
- All Category **II** equipment, delivered to site, is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed riser system.
- Monitoring of functional tests after installation and connection to the unit in accordance with an approved test programme.
- Issue of site installation report.

1.13 Maintenance and repair

1.13.1 It is the Owner's/Operator's responsibility to ensure that an installed riser system is maintained in a safe and efficient working condition in accordance with the manufacturer's and design specification.

1.13.2 When it is necessary to repair or replace components of a riser system, any repaired or spare part is to be subject to the equivalent certification as the original, *see* 10.2.

1.14 Plans and data submissions

1.14.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2*
Plans and data

2.1 General

2.1.1 Sufficient plans and data are to be submitted to enable the design to be assessed and approved. The plans are also to be suitable for use during construction, installation, hydrotesting, survey and maintenance of the riser system.

2.1.2 In general, engineering drawings and documents should be submitted electronically.

2.2 Specifications

2.2.1 Adequate design specifications, appropriate in detail to the approval required, are to be submitted for information.

2.2.2 Specifications for the design, construction and fabrication of the riser system, structure and associated equipment are to be submitted. The specifications are to include details of materials, grades/standards, consumables, construction and installation procedures and modes of operation with applicable design criteria. The specifications are also to include the proposed design codes.

2.2.3 Specifications and documentation are to be submitted, covering all instrumentation and monitoring systems proposed to cover the fabrication, installation and operating phases of risers, fittings and equipment.

2.3 Plans and data to be submitted

2.3.1 Plans and data covering the following items are to be submitted for approval, as relevant:

- Bend stiffeners.
- Bend stiffeners latching mechanisms.
- Bend restrictors.
- Buoyancy arches and fittings.
- Buoyancy modules.
- Construction and laying procedures.
- Corrosion protection system.
- Curvature bending stiffeners.
- Details of all attachments.
- Details of riser system control and communications.
- Details of sea bed.
- Emergency shut-down system and other safety devices, including pressure transient (surge) relief.
- End fittings.
- Instrumentation and communication line diagrams.
- Layout of risers and associated platform arrangements, including protection of risers.
- Leak detection system and hardware.
- Location survey showing name, latitude and longitude of terminal locations, location of isolating valves, position of platforms or other fabrications, shipping channels, presence of cables, pipelines and wellheads, etc.
- Mid water arches
- Quality Control and NDE procedures.
- Riser dimensions.
- Riser material specifications, including appropriate test results.
- Riser support details.
- Riser wall thickness tolerances.
- Sizes and details of expansion loops, reducers, etc.
- Test schedules for communication systems, controls, emergency shut-down systems and other safety devices, which are to include the methods of testing and test facilities provided.
- Tether arrangements
- Type and thickness of corrosion coating.
- Type and details of all pig traps, valves and control equipment, etc.
- Welding specification, details and procedures.

2.3.2 The following supporting plans and documents are to be submitted:

- Reference plans and listing of standard components, e.g., tees, reducers, connectors, valves, elbows, etc.
- Reference plans of anodes, sleeves, etc.

2.4 Calculations and data

2.4.1 The following is to be submitted where relevant to the riser system:

- Analyses of riser system behaviour including: strength, buckling, vortex shedding, on-bottom stability, displacements, vibration, fatigue, fracture and buckle propagation and minimum bend radii.
- Buoyancy and stability data for all risers.
- Burst pressure of flexible risers.
- Calculations and documentation of all design loads covering: manufacture, installation and operation.
- Corrosive nature of line contents.
- Corrosive nature of sea-water and sea bed soils.
- Current, tidal current and storm surge velocities and directions.

- Design cathodic protection potential.
- Damaging tension of flexible risers.
- Design life.
- Design pressure and temperature.
- Design throughput.
- Fluid to be conveyed. (The maximum partial pressure and dew point of H_2S , CO_2 and H_2O for gas risers).
- Ice conditions, which may affect riser system.
- Leak detection accuracy and response.
- Maximum and minimum operating temperatures including distributions along the riser.
- Maximum and minimum temperatures of water and air.
- Maximum operating pressure.
- Maximum Excursion Envelopes (MEEs) for riser system (in the x, y and z axes) to prevent damage. MEEs to be provided in the operational and survival conditions, with the mooring system in connected and disconnected (where appropriate) conditions.
- Marine growth density and thickness profiles (varying with water depth) plotted against time, over the field life.
- Product density.
- Sea bed geology and soil characteristics including stability and sand waves, etc.
- Sea bed topography and bathymetry in way of riser system and any possible deviation or future development.
- Seismic activity survey.
- Test pressure to be applied.
- Type, activity and magnitude of marine growth predicted.
- Wave heights, periods and directions.
- Wind velocities and directions.

2.5 Operations Manual

2.5.1 The allowable modes of operation including the maximum and minimum internal pressure, product temperature and flow rate together with the operating and maximum environmental criteria on which classification is based are to be stated in the unit's Operations Manual, as required by*Pt 3, Ch 1, 3 Operations manual*.

2.5.2 The Manual is to contain instructions and guidance on any actions which need to be taken to satisfy environmental considerations and the safe operation of the riser system.

■ *Section 3* **Materials**

3.1 General

3.1.1 The type and grade of materials chosen for the risers, valves and associated equipment are to be in accordance with the Rules for Materials or a recognised National or International Standard. In cases when a specification is not covered by LR's Rules, full details of the material specification, testing documentation and all properties are to be submitted for approval.

3.1.2 Materials are to be selected in accordance with the requirements of the design in respect of carriage of the product, strength, fatigue, fracture resistance and corrosion resistance.

3.1.3 Due consideration is to be given to temperature and other environmental conditions on the performance of the material, including toughness at the minimum operating temperature, the effects of corrosion, and other forms of deterioration both in service and whilst being stored or handled.

3.1.4 Riser material for H_2S -contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in* H_2S *-containing Environments in Oil and Gas Production, see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*

3.1.5 Steel grades for operation in areas where the design air temperature is below minus 20°C and in severe ice conditions (e.g., arctic waters), will be specially considered.

3.1.6 An approved system of corrosion control is to be fitted, where appropriate. Full details are to be submitted, *see Pt 8, Ch 1 General Requirements for Corrosion Control*.

■ *Section 4* Environmental considerations

4.1 Environmental factors

4.1.1 The Owner or designer is to specify the environmental criteria for which the riser system is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters.

4.1.2 The extreme environmental criteria to be taken into account in the riser system design are, in general, to be based on a return period of:

(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a Fixed Location.

See also Pt 4, Ch 3, 4 Structural design loads.

4.2 Environmental factors

4.2.1 The following environmental factors are to be considered in the design of the riser system:

- Air and sea temperatures.
- Current.
- Fouling.
- Ice.
- Water depth.
- Wave.
- Wind.

4.2.2 Environmental factors to be accounted for in the design loadings are contained in *Pt 4, Ch 3, 4 Structural design loads* together with the additional considerations below.

4.3 Waves

4.3.1 When using acceptable wave theories to determine local wave velocities for smooth cylindrical members, appropriate hydrodynamic coefficients should be used. These values should be modified to account for marine growth, for proximity to the sea bed, or structural members on the unit.

4.4 Current

4.4.1 Where a current acts simultaneously with waves, the effect of the current is to be included. The current velocity is to be added vectorially to the wave particle velocity. The resultant velocity is to be used to compute the total force.

4.4.2 In the absence of more detailed information, the distribution of current velocity with depth may be assumed to vary according to the 1/7th power law.

4.5 Vortex shedding

4.5.1 Consideration is to be given to the possibility of vibration of structural members due to von Karman vortex shedding. (This is to apply to wind on exposed risers, and to wave and current on immersed risers).

4.6 Ice

4.6.1 Riser systems intended for operation in ice are to be designed to minimise the effect of ice loading. Proposals are to be submitted for consideration.

Section 5
Design loadings

5.1 General

5.1.1 All modes of operation are to be investigated using realistic loading conditions, including buoyancy, unit motions and gravity loadings and operational loads (temperature, pressure, etc.) together with relevant environmental loadings due to the effects of wind, waves, currents, vibrations, ice, and where necessary, the effects of earthquake, sea bed supporting capabilities and friction, temperature, fouling, etc.

5.1.2 The design of the riser system is to take account of all loads which can be imposed during its service life.

5.1.3 The design is also to take account of loads related to the construction, transportation and site installation stages.

5.2 Dead loads

5.2.1 All gravity loadings are to be taken into account and should include self-weight of the riser system and attachments. The deadweight of contents is to be included.

5.2.2 Buoyancy of risers including attached equipment is to be taken into account.

5.2.3 Constraints and loads arising from supports and attachments should be taken into account. Also any scour or subsidence of sea bed should be assessed.

5.3 Live loads

5.3.1 Static pressure, pressure surge transients and any peak 'hammer-blow' effects are all to be considered, together with corresponding temperatures.

5.3.2 Dynamic inertial vibrations and flutter induced by any activation, including vortex shedding, are to be considered.

5.4 Environmental loads and motions

5.4.1 The environmental loading on a riser system and its motion responses are to be determined for at least the design environmental conditions given in Section 6. Dynamic effects are to be considered.

5.4.2 The loads and motions can be established by model testing or by suitable calculations or both. The possibility of resonant motion is to be fully investigated.

5.4.3 Account is to be taken of the effect of marine growth. Both increase in the dimensions and the change in surface characteristics are to be considered.

5.4.4 Where model testing is to be adopted:

(a) the test programme and the model test facilities are to be to LR's satisfaction;
(b) the relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined;
(c) the tests are to be of sufficient duration to establish low frequency motion behaviour; and
(d) the model testing is required to give suitable data pertaining to both strength and fatigue design aspects of the riser system.

5.5 Other loadings

5.5.1 Loads imposed during site installation, including those due to motion of the laying ship/unit, are to be assessed and taken into account. The curvature taken up during laying and loads imposed thereby are to be assessed and arrangements made for laying procedures to avoid any damage or overstress.

5.5.2 Hydrostatic effects are to be included in the design. Hydrostatic loading can be taken as the difference between internal and external pressures, as appropriate.

5.5.3 The riser system design should also take account of accidental loading, where relevant, and required test loads, *see* Section 9.

5.5.4 The riser system is to be designed to withstand the most unfavourable combinations of pressure, temperature and environmental loadings under normal operating conditions combined with the effects of the most severe single fault that might arise in the positioning system.

5.5.5 Scouring effects are to be considered for the support conditions of steel flexible risers at the touchdown locations.

■ *Section 6* **Strength**

6.1 General

6.1.1 This Section defines the strength requirements, including static and dynamic aspects, for welded steel riser systems, flexible riser systems and hoses.

6.1.2 The design is to be analysed in accordance with acceptable methods and procedures and the resultant stresses or factors of safety determined.

6.1.3 In general, the strength of the riser system is to be determined from a three-dimensional analysis. Only if it can be demonstrated that other methods are adequate will they be considered.

6.1.4 The riser system is to be designed such that under transient operating conditions the maximum allowable operating pressure may not be exceeded by more than 10 per cent.

6.2 Structural analysis

6.2.1 The loading combinations considered are to represent all modes of operation so that the critical design cases are established.

6.2.2 All loads applicable to the design, as defined in *Pt 3, Ch 12, 5 Design loadings*, are to be fully covered in the loading combinations.

6.2.3 A fully representative number of design cases are to be defined, each of which should be associated with appropriate environmental conditions and allowable yield ratios or factors of safety. The design cases are to cover all critical aspects of riser system installation, testing and operation.

6.2.4 A detailed analysis of the riser system, including interaction with pipeline and expansion loop is to be carried out. This is to take account of thermal, hydrodynamic, gravity, buoyancy and pressure effects and vessel motions. Modelling is to describe riser geometry and stiffness, and soil interaction, including loss of contact.

6.2.5 Riser supports and stiffener bend restrictor forces are to be determined, and strength checks carried out.

6.3 Flexible risers and hoses

6.3.1 The design of flexible risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the flexible risers, *see Pt 3, Ch 17, 1.2 Recognised Codes and Standards*.

6.3.2 For all critical loading combinations relevant to the design axial loading, internal/external pressure and radius of curvature are to be considered in a rational manner.

6.3.3 Other factors which adversely affect the integrity of the riser such as abrasion, ageing, corrosion, fatigue and fire are also to be considered.

6.3.4 For fatigue *see* 6.4.6; however, endurance curves should also account for fluid permeation through polymers and potential accidental ingress of sea-water resulting from damage to the external sheath.

6.3.5 Special attention is to be given to riser end fittings to ensure effective bonding, pressure containment and load transfer.

6.3.6 In general, riser displacements are to achieve acceptable clearances with adjacent risers, mooring lines, unit structures and the sea bed. However, in extreme cases interference may be allowed, *see Pt 3, Ch 12, 1.5 Damage protection*.

6.3.7 Critical design parameters are to be demonstrated by means of appropriate tests and calculations.

6.4 Welded steel risers

6.4.1 The design of steel risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the steel risers, *see Pt 3, Ch 17, 1.2 Recognised Codes and Standards*.

6.4.2 **Yielding**: For any particular location, two stress intensity calculations will be required, as follows:

(a) Hoop stress calculations are to be made utilising the minimum specification wall thickness less corrosion allowance, as appropriate.
(b) All axial stresses arising from end load, bending moment, shear and torsion are to be combined with hoop stress to give an equivalent stress based on the Mises-Hencky criterion to conform with specified yield ratio limits. For this purpose, nominal section dimensions may be used.

6.4.3 **Vortex shedding response:**

(a) The effects of vortex-induced oscillations are to be accounted for. The effect of axial forces on natural frequency is to be included.
(b) The restraining effect of external spans, and relief due to wave and current directionality may be included provided that sufficient environmental data is available.
(c) In all cases, the effect of vortex shedding on fatigue life is to be checked.

6.4.4 **Buckling**. Local and overall buckling of the riser is to be checked for all locations and loading conditions for which free spans may arise. The worst combinations of axial and lateral loading are to be considered.

6.4.5 **Stress concentrations**. The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of the load-carrying elements.

6.4.6 **Fatigue:**

(a) Fatigue damage due to cyclic loading is to be considered in the design of the riser. The cyclic loading due to internal (contents) pressure fluctuations and external environmental loadings is to be taken into account. The extent of the fatigue analysis will be dependent on the mode and area of operations.
(b) Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in *Pt 4, Ch 5, 5 Fatigue design*, or other acceptable method, and the fatigue life calculations are to be based on the relevant stress range/endurance curves applicable to the service environment incorporating appropriate stress concentration factors .
(c) The minimum factors of safety on fatigue life are not to be less than as required by *Pt 4, Ch 5, 5 Fatigue design*.

6.4.7 **Plastic analysis**. Where plastic design methods are to be employed, the load factors will be specially considered.

6.5 Pig trap

6.5.1 Pig traps are to be designed to the requirements of a recognised pressure vessel code and since they are considered as part of the riser and associated equipment the hoop stress is not to exceed 60 per cent of the minimum yield stress of the material.

6.6 Riser supports and attachments

6.6.1 The riser supports and other attachments are to be designed to meet suitable structural design codes. Where the supports are attached to the structure of the unit the permissible stresses in the structure are to comply with *Pt 4, Ch 5, 2 Permissible stresses*.

6.7 Mechanical items

6.7.1 The design of components such as valves and similar apparatus is to be in accordance with an acceptable design method or recognised Code or Standard.

■ Section 7 Welding and fabrication

7.1 General

7.1.1 Welding, weld procedures and approval of welders are to be in accordance with the general requirements of *Pt 4, Ch 8 Welding and Structural Details*. When agreed with LR, the fabrication of riser systems may be in accordance with a recognised Code or Standard, *see* Appendix A.

7.1.2 The proposals for NDE procedures are to be agreed with LR prior to the commencement of construction.

7.1.3 All butt welds are to be subjected to 100 per cent NDE. Examination by radiography is to be to a Standard acceptable to LR, e.g., ISO 17636: *Non-destructive testing of welds – Radiographic testing of fusion welded joints*, with acceptance criteria as detailed in the Construction Code, or BS 4515: *Specification for welding of steel pipelines on land and offshore*, if not specified in the Code. Proposals for examination by ultrasonics are to be submitted for review and acceptance.

7.1.4 All defective sections of welds are to be cut out, carefully re-welded and re-examined.

7.1.5 Weld procedures for repairs and alterations are to be qualified and approved by LR.

■ Section 8 Installation

8.1 General

8.1.1 Specifications covering the site installation procedures are to be submitted for approval.

8.2 Location Survey

8.2.1 Specifications, plans and data are to comply with *Pt 3, Ch 12, 2.3 Plans and data to be submitted*. Additional data is to be submitted specifying sea bed preparation, extent and means of execution and survey prior to installation.

8.2.2 The construction specification is to specify the tolerance within which the riser system is to be positioned.

8.3 Installation procedures

8.3.1 The equipment used for operations is to be agreed by LR for the processes specified.

8.3.2 Individual risers, equipment, fittings and sub-assemblies are to be handled and stored with care, especially components with anodes or heavy anode bracelets. No components are to be stored in a manner which will cause damage or deformation.

8.3.3 All components and sub-assemblies are to be inspected before installation and be approved to the satisfaction of the Surveyor.

8.3.4 The installation of the riser is not to introduce any unscheduled loading and the transfer of loading to riser supports is to be shown to be in accordance with design specifications.

8.3.5 All monitoring systems are to be operated and calibrated to the Surveyor's satisfaction during all laying and installation operations.

8.4 Completion Survey

8.4.1 As soon as is practicable following installation and prior to start-up, a survey of the entire riser system is to be carried out.

■ Section 9
Testing

9.1 Hydrostatic testing

9.1.1 The requirements of *Pt 3, Ch 12, 1.10 Equipment certification*, 1.11 and 1.12 regarding certification and testing are to be complied with.

9.1.2 **Steel risers:**

(a) The riser system is to be hydrostatically tested after installation. Hydrostatic Testing Procedures are to comply with recognised international Codes and Standards.
(b) A written procedure is to be developed before hydrostatic testing commences. The acceptance criteria are to be agreed by LR.

9.1.3 **Flexible risers**. For flexible risers, pressure testing includes acceptance tests in the factory and hydrostatic test after installation. The acceptance test pressure should be in accordance with international Codes and Standards for flexible risers.

9.1.4 It is permissible to have pressure variations during a hydrostatic test provided they can be explained in terms of temperature changes and/or motions of the riser system.

9.1.5 In order to calculate the effect of temperature on pressure, it is essential that the temperature of the fluid in the pipe is measured and recorded at the same time as each pressure measurement is made and recorded. Ambient air or sea-water temperature are not relevant.

9.1.6 As a minimum, the temperature is to be measured near each end of the riser. Preferably at least one transducer on the sea bed part of the riser should also be provided.

9.1.7 Temperature sensors attached to the outside of the steel wall of a riser and insulated from the thermal effects of the sea are acceptable provided the test medium has been in the riser for at least 24 hours before the test is started, in order to allow the temperature of the fluid and steel to stabilise.

9.1.8 When conducting a hydrostatic test of a riser, the following requirements are to be complied with:

(a) The pressure (and temperature, if applicable) is to be continuously recorded for the duration of the test on a chart recorder.
(b) The chart is to be signed by the Surveyor at the beginning and end of the test.
(c) Pressure (and temperature, if applicable) readings are to be made at intervals not greater than 30 minutes and tabulated.
(d) Where temperature readings are to be taken the line is to be filled at least 24 hours before the test to enable the temperature to stabilise.
(e) The results of a hydrostatic test are to be recorded by a dossier containing the following:

Copies of all charts made during the test.
Copies of all tables of pressure readings (and temperature readings where applicable) made during the test.
Copies of calibration certificates for the pressure recorders used.
Calculations demonstrating temperature correction to pressure change where applicable.

9.1.9 The sections of riser are to be hydrostatically tested at the place of manufacture in accordance with *Ch 6 Steel Pipes and Tubes* of the Rules for Materials or the relevant National Standard.

9.1.10 Before a consent to start-up a riser can be given, evidence of a satisfactory hydrostatic test is to be provided. The evidence is to relate to a test completed during the 12 months prior to the date of application for the consent to start up.

9.2 Buckle detection

9.2.1 An adequate examination is to be carried out to determine that the completed riser is free from buckles, dents or similar damage.

9.3 Testing of communications, controls and safety systems

9.3.1 Communication systems, remote and automatic controls, emergency shut-down systems and other safety devices are to be tested in accordance with the approved test schedules required by *Pt 3, Ch 12, 2.3 Plans and data to be submitted*.

Section 10
Operation and repairs

10.1 Operation procedures

10.1.1 A written operation procedure is to be prepared and issued prior to the riser system being put into operation. One operation procedure may, where applicable, cover several riser systems of the same type.

10.1.2 Where a riser system forms part of a system covering other lines, platforms, terminals, etc., the operating procedure is to embrace those parts of the entire system which are relevant to the operation of the riser system.

10.1.3 In order to minimise the risk of damage to the riser system, it is the Owner's/Operator's responsibility to ensure that supply boat approach routes to the installation are strictly controlled. A mooring procedure is to be produced which clearly indicates safe and hazardous anchoring areas.

10.1.4 Operation procedures are to be written in English with translations into other languages, as necessary, for the operating personnel involved.

10.2 Repairs

10.2.1 It is the Owner's responsibility to inform LR of any defects found. The exact location, nature and extent of the defects are to be stated. The requirements of *Pt 3, Ch 12, 1.13 Maintenance and repair* are to be complied with.

10.2.2 Plans and particulars of any proposed repairs are to be submitted for approval. All repair work is to be carried out to the satisfaction of LR's Surveyors.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are supplementary to those given in the relevant Parts of the Rules, and apply to buoys, deep draught caissons, turrets and other special structures. Requirements are given in this Chapter for the following special structures which are used in association with floating units:

(a) Subsea buoyant vessels.

(b) Mooring towers.

1.1.2 The Rules also cover mooring yokes, loading arm arrangements, hinged joints and support structures on floating units.

1.1.3 These Rules assume that floating moored units will be tethered with catenary-type mooring cables attached to the sea bed by anchors, gravity blocks or piles. Proposals for the use of pivot arms or other methods of tethering will be specially considered, *see Pt 3, Ch 13, 4 Mooring arms and towers* and *Pt 3, Ch 13, 6 Mechanical items*.

1.1.4 Requirements for positional mooring systems are given in *Pt 3, Ch 10 Positional Mooring Systems*.

1.1.5 Foundations for mooring systems are to comply with *Pt 3, Ch 14 Foundations*, *see also Pt 3, Ch 13, 4.1 General*.

1.1.6 Buoys and other floating units may be fitted with pipelines or risers for loading and unloading linked ship/unit and additionally be fitted with crude oil bulk storage tanks, process plant facility, power generating capability, accommodation modules and similar facilities.

1.1.7 Units with crude oil or liquefied gas bulk storage tanks and/or production and process plant are to comply with the applicable requirements of *Pt 3, Ch 3 Production and Storage Units* and *Pt 3, Ch 8 Process Plant Facility*.

1.2 Definitions

1.2.1 The definitions in this Chapter are stated for Rule application only and may not necessarily be valid in any other context.

1.2.2 **Buoy**. A floating mooring facility secured by a flexible tether or tethers to the sea bed, but excluding the other unit types defined in *Pt 1, Ch 2, 2.1 General definitions*.

1.2.3 **Deep draught caisson units** are single column floating units which operate at a deep draught in relation to their overall depth.

1.2.4 **Subsea buoyant vessel**. A submerged structure with positive buoyancy secured by a flexible tether or tethers to the sea bed and used to support flexible risers.

1.2.5 **Mooring tower**. A structure for single point mooring which is attached directly to the sea bed. The tower may be a single or multiple member structure and can be fixed to the sea bed, or articulated by means of a universal joint attached to the sea bed.

1.2.6 **Single-point mooring**. An offshore mooring facility based on a single buoy or single tower. A single-point mooring will allow a moored ship/unit to weathervane, and is normally associated with the transfer of oil, gas, and other fluids to or from the ship/unit. The following are among the most common types of single point moorings:

- CALM – catenary anchor leg mooring.
- SALM – single anchor leg mooring.
- Mooring tower.
- Turret mooring.

1.2.7 **Multi-point mooring**. A mooring facility embodying a number of separate buoys or mooring points. A multi-point mooring terminal is used to hold a ship/unit on a general constant heading and can incorporate facilities for the transfer of oil, gas and other fluids.

1.2.8 **Turret mooring**. A single-point mooring variant where the slewing function, allowing complete or partial weathervaning, forms an integral part of the unit. Turret mooring is mainly applicable to permanently moored surfactype units.

1.2.9 **Spread mooring**. A multi-line mooring system designed to maintain an offshore unit on an approximately fixed heading.

1.2.10 **Mooring hawser**. A mooring rope connecting a ship/unit to a single-point mooring or buoy. Only a hawser permanently attached to a single-point mooring or buoy will be included in the classification of the installation.

1.2.11 **Mooring yoke**. A structural arm connecting a ship/unit to a single-point mooring or buoy. A yoke is normally used for permanently moored units.

1.3 Pipelines and power cables

1.3.1 Where pipelines, power cables, etc., are incorporated into or trail from single-point mooring installations, details of their number, position, size and method of attachment are to be submitted in order that their effect on wave forces, etc., acting on the structure, and of any restraining forces that they may impose, can be assessed.

1.3.2 For units with production and process plant, the boundaries for classification are to be as defined in *Pt 3, Ch 8, 1.3 Scope*.

1.3.3 Pipelines carrying high pressure fluids, cables carrying high energy electricity supplies and cable carrying control signals critical to the safety of the unit, or to its operational reliability, are to be located in suitable positions on the unit in order to avoid accidental damage by moored ships/units, maintenance craft, or other sources which may cause large impact loads. Where this is impracticable, they are to be adequately protected and the arrangements submitted for approval.

1.3.4 If a floating unit is to be tethered in way of an existing wellhead, pipelines or high energy power cables, sufficient plans and details are to be submitted to enable Lloyd’s Register (LR) to fully assess the following:

(a) The nature and size of the wellhead, pipeline or cable.
(b) The methods and arrangements to be employed to avoid accidental damage during the on-site installation.
(c) Method and means for emergency release.

NOTE

This information is required whether the pipework and cables are permanent or temporary and whether they are situated above water or subsea.

1.3.5 Where a caisson, buoy or mooring tower is fitted with risers/pipelines intended for the loading or discharge of oil or gas, the Rules consider the following as the main boundaries of the installation for classification, unless agreed otherwise with LR:

(a) Any part of the pipeline system located on the structure including the riser connector valves, but excluding the risers is considered part of the installation.
(b) The shut-down valve at the export outlet from the pipeline system to the storage or offloading facility.
(c) Where a floating or trailing riser is stowed on a reel, the Rules apply to the reel, but not the flexible riser, *see also Pt 3, Ch 12 Riser Systems*.

1.3.6 Where power cables are attached to the structure for the purpose of supplying electricity to a moored ship/unit, etc., the extent, if any, of cable included in the class of the structure will be specially considered by LR.

1.4 Class notations

1.4.1 The Regulations for classification, and the assignment of class notations, are given in *List of abbreviations*, to which reference should be made.

1.4.2 Buoys and single-point moorings complying with the requirements of this Chapter and the relevant Parts of the Rules, will be eligible for the assignment of one of the following type class notations, as applicable:

- Mooring buoy.
- Single-point mooring buoy.
- Tanker loading terminal.
- Mooring tower.
- Articulated mooring tower.

1.4.3 Deep draught caisson units will be eligible for the assignment of a type class notation in accordance with the unit's function, *see Pt 3, Ch 3 Production and Storage Units*. In addition a descriptive note will be added in the Class Direct website, e.g., '**Deep draught caisson unit**'.

1.4.4 Associated integral mooring equipment, including anchors, mooring lines and their connections to the sea bed, will generally be included in the class of an installation, *see Pt 1, Ch 2, 2.1 General definitions*. For mooring hawsers, *see Pt 3, Ch 13, 5 Mooring hawsers and load monitoring*.

1.4.5 In the case of ship units the following components will generally be considered from the Classification aspects as part of the installation:

- Internal and external turrets.
- Mooring arms and yokes.
- Associated mooring equipment and mooring lines attached to the unit, and their anchors or connections to the sea bed.

1.4.6 Units with oil or liquefied gas bulk storage tanks or production/process plant may be assigned type class notations in accordance with *Pt 3, Ch 3 Production and Storage Units*.

1.4.7 Product riser systems which comply with the requirements of *Pt 3, Ch 12 Riser Systems*will be eligible for the special features notation **PRS**.

1.4.8 When a unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional class notation may be assigned in accordance with *List of abbreviations*.

1.4.9 Vessels designed for offshore loading should have the arrangements for offshore loading designed and constructed in accordance with suitable standards. For vessels classed LR, the requirements are outlined in *Pt 7, Ch 6 Arrangements for Offshore Loading* of the Rules for Ships.

1.5 Scope

1.5.1 The following additional topics applicable to the type class notation of buoys and special installations are covered by this Chapter:

- General arrangement.
- Structural arrangements.
- Supporting structures to mooring systems and marine risers.
- Structural arrangement of oil storage tanks.
- Piping and piping systems.
- Watertight subdivision.
- Subsea buoyant vessels.
- Mooring towers.
- Turret structures.
- Gravity base.
- Mechanical parts, including bearings, universal joints and swivels.
- Mooring arms, yokes or hawser.
- Piping and cargo transfer systems located on the unit.
- Hazardous areas and ventilation.
- Pollution prevention.

1.6 Installation layout and safety

1.6.1 In principle units engaged in production and/or crude oil storage are to be divided into main functional areas in accordance with the requirements of Chapter 3.

1.6.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration. Additional requirements for the fire safety on units with production and process plant are given in *Pt 7, Ch 3 Fire Safety*, *see also Pt 1, Ch 2, 1 Conditions for classification*.

1.6.3 Additional requirements for safety systems and hazardous areas are given in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

1.6.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from production and wellhead areas.

1.6.5 Suitable arrangements are to be incorporated in the design to enable supply and maintenance craft to come along side as necessary and to moor safely while maintenance staff and equipment are being transferred to, or from, the installation.

1.6.6 Protection against damage which might otherwise be caused by impacts from moored ships/units over-riding the mooring installations or by supply and maintenance craft coming along side is to be provided. This protection is to include suitable fendering, adequately reinforced landing platforms or their equivalent, *see also Pt 4, Ch 3, 4.1 General*.

1.6.7 Proper means of access are to be provided for maintenance and survey. Arrangements are to include a suitable platform or other landing area. It is the Owner's responsibility to provide suitable ladders, where the height of the deck is too great to facilitate direct access of personnel from maintenance craft.

1.7 Watertight and weathertight integrity

1.7.1 The general requirements for watertight and weathertight integrity are to be in accordance with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines* .

1.7.2 Floating units and subsea buoyant vessels are to have adequate buoyancy and stability in both intact and damage conditions, *see Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*. They are to be sub-divided by watertight divisions, especially in zones where there is a risk of collision.

1.7.3 When requested, LR will give special consideration to the incorporation of equivalent approved means of protection against accidental sinking on buoys and subsea buoyant vessels. Where compartments are to be filled with foam, full details are to be submitted for approval.

1.7.4 The integrity of the weather deck of buoys and other floating structures is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in deckhouses fully complying with the Rules. Full details are to be submitted for approval.

1.8 Plans and data submission

1.8.1 Plans are to be submitted for approval as required by the relevant Parts of the Rules together with applicable plans, calculations and information to cover the additional topics listed in this Chapter, as applicable.

1.8.2 A single copy of the following supporting plans, data, calculations or documents are to be submitted:

- Anchors and tether system components.
- Motion envelopes (single-point mooring, risers and tethers, as applicable).
- Floating stability.
- Strength and fatigue of structural and mechanical parts.
- Design specification.
- Environmental report.
- General arrangement.
- Materials specification.
- Model test report.
- Operating instructions.
- Loadout and site installation procedure.

Section 2
Floating structures and subsea buoyant vessels

2.1 Floating structures

2.1.1 The structural design and the general hull strength of buoys and deep draught caissons are to comply with the requirements of *Pt 4 STEEL UNIT STRUCTURES* taking into account the equipment weights and forces imposed on the structure.

2.1.2 The supporting structure below swivels and other equipment is to be designed for all operating conditions and environmental loads as defined in Part 4.

2.1.3 The structure and arrangement of units with crude oil bulk storage tanks and/or production and process plant are also to comply with the requirements of *Pt 3, Ch 3 Production and Storage Units* and *Pt 3, Ch 8 Process Plant Facility*, as applicable.

2.1.4 Critical joints, depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing), are to be avoided wherever possible. Where unavoidable, plate material with suitable through thickness properties will be required, *see Ch 3 Rolled Steel Plates, Strip, Sections and Bars*,*Ch 8 Aluminium Alloys* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Moored floating structures supporting multi-point mooring line arrangements are to be assessed for the maximum combined forces to which they may be subjected to in service.

2.1.6 Account is to be taken of wave slamming effects, where appropriate.

2.1.7 Floating structures, including highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures are to be assessed for local strength as required in *Pt 10 SHIP UNITS* and for fatigue damage due to cyclic loading in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

2.1.8 For mechanical items for bearings and swivels, *see Pt 3, Ch 13, 6 Mechanical items*.

2.2 Permissible stresses

2.2.1 The permissible stresses in floating structures are to comply with *Pt 4, Ch 5 Primary Hull Strength*, but the minimum scantlings of the local structure are to comply with *Pt 4, Ch 6 Local Strength*.

2.3 Subsea buoyant vessels

2.3.1 Where a classed installation is to be assigned the notation **PRS** in accordance with *Pt 3, Ch 12 Riser Systems*, riser systems incorporating subsea buoyant vessels are to comply with the requirements of this sub-Section.

2.3.2 Where subsea buoyant vessels are used in association with other systems, they will be specially considered from the classification aspects.

2.3.3 Subsea buoyant vessels are to be designed for all external operating loads and the maximum pressure head to which the structure may be subjected to in service or during installation, *see Pt 4, Ch 3, 4.1 General*.

2.3.4 The scantlings of the shell boundaries and framing are to be determined from an internationally recognised Pressure Vessel Code.

2.3.5 All vessels are to have positive buoyancy, when subjected to their design external loads, when any one internal compartment is flooded. Special consideration will be given to vessels with compartments filled with foam, *see* 1.7.

2.3.6 The local structure is to be suitably reinforced in way of the loads imposed by riser systems, and other external loads and the requirements of 2.1.4 are to be complied with as applicable.

2.3.7 Internal watertight bulkheads are to withstand the flooding of any single compartment. The scantlings of watertight bulkheads are to comply with *Pt 4, Ch 6 Local Strength*, with h_4 determined in accordance with 2.3.3.

■ Section 3
Turret structures

3.1 General

3.1.1 Turret structures supporting multi-point mooring line arrangements are to be assessed for the maximum combined forces to which they may be subjected to in service. The turret structure is to be suitable for the appropriate maximum single-point mooring line loads and in addition the critical mooring line group loadings.

3.1.2 Environmental criteria and loading are in general to be in accordance with *Pt 10 SHIP UNITS*.

3.1.3 Account is to be taken of wave slamming effects, where appropriate.

3.1.4 When an internal turret is designed as a stiffened shell, the scantlings of plating and stiffeners are not to be less than required by Table 7.7.1 in *Pt 4, Ch 6 Local Strength* as a deep tank bulkhead, using a load head h_4 measured vertically from the point of consideration to the top of the turret well.

3.1.5 Permissible stresses for direct calculations are to be in accordance with *Pt 4, Ch 5, 2 Permissible stresses*.

3.1.6 The sealing arrangements, where fitted, between internal turrets and circumturret well bulkheads will be specially considered.

3.1.7 The turret structure, including structural supports in way of bearings and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures, are to be assessed for local strength as required in Part 10 and for fatigue damage due to cyclic loading in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

3.1.8 Suitable access arrangements are to be provided to allow inspection and maintenance of turret structural and mooring system components during service. A planned procedure for the inspection of the structure and mooring system components is to be provided, as required by *List of abbreviations*.

3.1.9 Special consideration is to be given in design to load transfer together with the effect of hull deformations at the interface of the turret support structure with the main hull structure.

3.1.10 The scantlings of the circumturret well bulkheads, turret support arrangements and hull backup structure are to be in accordance with *Pt 10 SHIP UNITS*.

3.1.11 For mechanical items such as bearings and swivels *see Pt 3, Ch 13, 6 Mechanical items*.

3.1.12 The structure of hawsepipes and their supports is to be designed to withstand the imposed static and dynamic loads. Plating and framing in way of hawsepipes are to be reinforced as necessary. All relevant loads as defined in Chapter 3 are to be considered and the permissible stresses due to overall and local effects are to be in accordance with *Pt 4, Ch 5, 2 Permissible stresses*.

3.1.13 Hawsepipe components are to be of ample thickness and of a suitable size and arrangement to house the mooring cables efficiently. Due consideration is to be given, as far as practicable, to minimise the effects bending and chafing on the mooring cables.

■ Section 4
Mooring arms and towers

4.1 General

4.1.1 Mooring arms and towers are to be designed for the maximum mooring loads and direct wave loading to which they may be subjected in service, and design calculations are to be submitted. The loadings on lattice type structures are to be specially considered and agreed with LR.

4.1.2 The structure is to be designed for the most unfavourable of the following combined loading conditions:

(a) maximum gravity and functional loads.
(b) design environmental loads and associated gravity and functional loads.

(c) design environmental loads and associated gravity and functional loads after credible failures.

4.1.3 The structure is to be investigated for loading condition 4.1.2(c) to assess the effect of the failure of a single slender tubular (or similar) member. The permissible stress levels after credible failures are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*. When stress levels in the structure exceed permissible levels the slender tubular member is considered to be 'non-redundant', *see* 4.1.4 . This requirement does not apply to stiffened plate structures or mechanical items.

4.1.4 When the requirements of 4.1.3 are not met the intact structure is to be further investigated for loading condition 4.1.2(b) under the action of a 10000 year return period mooring load and associated gravity and functional loads. Non-redundant slender tubular (or similar) members should in general have sufficient ductility to resist failure, i.e., strain up to 21 per cent.

When this criterion is not met the following mitigating measures are required:

(a) clear identification of high stress areas.
(b) welding in high stress areas to be full penetration, as far as practicable.
(c) NDE in accordance with an agreed plan,*see also* Table 9.2.1 in*Pt 4, Ch 8 Welding and Structural Details*.
(d) minimum factor of safety of 2 on fatigue life, *see Pt 4, Ch 5, 5.6 Factors of safety on fatigue life*.
(e) inspection and test plans (fabrication and in-service) to be submitted for LR approval.
(f) operations manual to clearly specify critical areas and inspection requirements.

4.1.5 The permissible stresses in mooring arms and the attachment to floating units are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

4.1.6 Attention is to be paid to the detail design in fatigue sensitive areas. Mooring arms, towers, articulated and sliding joints are to be assessed for fatigue damage due to cyclic loading in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

4.1.7 All structures are to have adequate buckling strength and comply with *Pt 4, Ch 5 Primary Hull Strength*. Special attention is to be paid to the torsional buckling of mooring arms and design calculations are to be submitted.

4.1.8 Mooring towers are to be designed in accordance with an internationally recognised Code or Standard, *see* Appendix A.

4.1.9 Mechanical items and bearings are to comply with *Pt 3, Ch 13, 6 Mechanical items*.

4.1.10 Foundations to mooring towers are to comply with the requirements of *Pt 3, Ch 14 Foundations*.

4.1.11 If a classed unit is attached to a mooring tower which is not classed by LR, the mooring tower and its foundations are to be certified by LR or another acceptable organisation, *see Pt 1, Ch 2, 2.1 General definitions*.

■ *Section 5*
Mooring hawsers and load monitoring

5.1 Mooring hawsers

5.1.1 Mooring hawsers permanently attached to a classed installation and used to moor a shuttle tanker, or other ship/unit are included in the classification.

5.1.2 Mooring hawsers are to be of suitable material and construction for the intended service and are to be fitted with:

(a) a chafe chain assembly in accordance with Oil Companies International Marine Forum (OCIMF) *Recommendations for Equipment Employed in the Mooring of Ships at Single Point Moorings*, or equivalent; and
(b) a pick-up line to facilitate the picking up of the hawser by the ship/unit.

5.1.3 Testing and manufacturing inspections of ropes for mooring hawsers are to be in accordance with the following OCIMF Standards, or suitable alternative recognised National or International Standards:

- Prototype Rope Testing.
- Procedures for Quality Control and Inspection during the Production of Hawsers.

5.1.4 A single-point mooring hawser is to have a minimum rated strength of twice the maximum mooring load, *see* 5.1.5. In the case of a double mooring hawser comprising two individual ropes running to well separated fairleads, each hawser is to have a minimum rated strength of 1,5 times the total maximum mooring load. For classification purposes, the rated strength of a single-

point mooring hawser is to be taken as the 'New Wet Break Strength' (NWBS) of the particular hawser assembly, as defined in OCIMF Standards referenced in 5.1.3.

5.1.5 The maximum mooring load used to determine the required strength of a mooring hawser will also be regarded as the maximum allowable peak mooring load in service. This allowable load will be included in the limiting design criteria on which classification is based.

5.2 Load monitoring

5.2.1 Single-point mooring (SPM) installations are to be provided with an approved means of monitoring the load occurring in the mooring hawser connecting the SPM to the ship/unit (alternatively such equipment can be provided on the attending vessel, *see Pt 7, Ch 6, 3 Positioning, monitoring and control arrangements* of the Rules for Ships). This equipment is to be designed so that automatic warning is given to the ship/unit in the event that tension in the mooring hawser exceeds designated limits, *see* 5.1.5. Warning is to be given by both visual indication and audible alarm. Consideration will be given to alternative proposals such as provision of a 'weak link'. Full details of such proposals are to be submitted for LR approval.

5.2.2 The load level designated to initiate automatic warning is to be below the maximum allowable hawser load level by a sufficient margin to allow such steps to be taken as may be necessary, to prevent excessive loads, or to prepare for ship/unit disconnection from the SPM. It is recommended that two warning levels be incorporated, the first level at 60 per cent of allowable load and the second level at 80 per cent of allowable load. Where only one warning level is provided it should be set at no more than 70 per cent of allowable load.

5.2.3 The load level designated to initiate the automatic warning should be set giving due consideration to the safe working load of the chain stoppers fitted to the attending vessel.

5.3 Spare parts and maintenance

5.3.1 An adequate number of spare parts for the hawser system is to be provided on board a classed unit.

5.3.2 A planned maintenance and replacement scheme for mooring hawsers are to be submitted to LR and suitable instructions are to be included in the Operations Manual.

■ *Section 6*
Mechanical items

6.1 General

6.1.1 In general all machinery, control and electrical items are to comply with the requirements of the appropriate sections in *Pt 5 MAIN AND AUXILIARY MACHINERY* and *Pt 6 CONTROL AND ELECTRICAL ENGINEERING*. For pressure vessels, *see Pt 3, Ch 8, 4 Pressure vessels and bulk storage*.

6.1.2 This Section covers mechanical items of turrets and swivels including bearings, hinges, universal joints and seals, etc. Turret structures are to comply with *Pt 3, Ch 13, 3 Turret structures*.

6.1.3 Sufficient plans, data and specifications are to be submitted to enable the mechanical arrangements to be assessed and approved.

6.1.4 Plans and data covering the following items are to be submitted for approval, as relevant:

- Structural arrangements.
- Materials specification.
- Lubrication system.

6.1.5 The following supporting plans and documents are to be submitted:

- General arrangement.
- Design specification.
- Design calculations.
- Surveillance program.

6.2 Design

6.2.1 The design of joint and hinges should minimise any stress concentrations, particularly where significant dynamic loadings may occur.

6.2.2 Suitable strength and fatigue analyses of joint or hinge assemblies are to be carried out, where appropriate.

6.2.3 It is to be considered that vibration levels in the associated pipe work and structure of the swivel are to be kept to a minimum level to avoid bearing-associated failures.

6.3 Bearings

6.3.1 Components in swivel support systems are to be designed for the operating forces, moments and pressures intended, taking into account, where necessary, survival, tow out, damaged, fatigue and other operating conditions. Design calculations are to be submitted.

6.3.2 Rolling element, pad and journal bearings used in swivel units are to be designed for the static and dynamic loadings which are expected in service. Bearing pressure and fatigue life calculations are to be submitted.

6.3.3 Bearings, joints, etc., are to be suitable to withstand the application of all loads expected during service life. The effect of construction tolerances of the bearing and bearing supports is to be considered. The maximum tolerances recommended by the bearing supplier should be used. The maximum design loadings are to be determined in accordance with *Pt 4, Ch 3, 4 Structural design loads*.

6.3.4 The design of bearings, joints, etc., is to be in accordance with an acceptable design method or an internationally recognised Code or Standard. For acceptable Codes for roller and ball bearings, *see* Appendix A.

6.3.5 Bearing design is to include the effects of low and high frequency response loadings, where appropriate.

6.3.6 The effects of motions, for a range of typical operating modes, are to be considered in the design.

6.3.7 Where necessary, suitable lubricating arrangements are to be fitted to all adjacent bearing surfaces to maintain an adequate and continuous supply of lubricant to the surfaces during all unattended periods. Gravity-fed or non-power-operated systems are to be preferred for non-manned installations.

6.3.8 Consideration is to be given to monitoring turret roller bearings in service by condition monitoring the bearing lubrication fluid. Details to be submitted to LR.

6.3.9 Primary bearing surfaces are to be adequately protected from deterioration caused by the ingress of seawater and other contaminants by a system of seals or other suitable alternative methods. Sealing arrangements for bearing systems are to contain lubrication and are to be designed for their intended service life or field life of the installation as applicable.

6.3.10 Data should be submitted to substantiate the fitness of the bearing for the field life of the installation or 20 years, whichever is greater. Consideration will be given to the reduction of this life where an agreed change-out programme is implemented.

6.3.11 Classification will be based on a review of the designers calculations.

6.3.12 In all cases where the bearing dynamic load is more than 50 per cent of the basic load dynamic rating, supporting justification is to be submitted.

6.3.13 The suitability of bearings selected for heavily loaded applications should be checked to ensure that their basic static load rating is adequate, taking into account their static safety factor.

6.3.14 Consideration is to be given to the use of lubricants with EP additives where the bearing loads are high.

6.3.15 Consideration is to be given to rolling element bearings; those which cannot be replaced whilst vessel/buoys are at location are to be designed for L5 bearing life.

6.3.16 Consideration is to be given to ensuring that excessive lubrication is avoided in tilting pad bearings and that the Pressure Velocity is within the recommended limits. For acceptable limits, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

6.3.17 Where grease lubrication is being used on a loading buoy bearing, frequent grease sampling and system monitoring are to be considered.

6.4 Bearing support structures

6.4.1 Bearing support structures are to be assessed for fatigue damage due to cyclic loading in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

6.4.2 Permissible stress levels in supporting structure are to be in accordance with those specified in *Pt 4, Ch 5, 5 Fatigue design*.

6.4.3 A fatigue analysis of structural items is to be carried out in accordance with *Pt 4, Ch 5, 5 Fatigue design*Factors of safety on fatigue life is to be determined after consideration of the redundancy of the structure, the accessibility of the item being considered, the consequence of failure, etc. Minimum required factors of safety are given in *Pt 4, Ch 5, 5 Fatigue design*.

6.4.4 Consideration is to be given to improve bearing support structure stiffness to prevent substantial increase in the bearing loading.

6.4.5 Consideration is to be given to the integrity of the weld attachments for the support structures.

6.4.6 Cracking of bearing housings at stress concentrators due to bearing wear is common in roller bearings and should be considered as a potential damage mechanism.

6.4.7 The strength and fatigue analysis of bearing supports is to consider the effect of construction tolerances of the bearing and bearing supports. The maximum tolerances recommended by the bearing supplier should be used.

6.5 Seals

6.5.1 Leakage of lubrication fluid and subsequent ingress of sea-water is to be prevented by installing a suitable system of seals.

6.5.2 The seals employed are to be of a suitable material for the intended service.

6.5.3 Sealing elements installed are to be capable of safely absorbing the required deflection or, alternatively, adequate provisions for slippage are to be incorporated in the design.

6.5.4 A lubrication leakage detection system is to be installed in order to monitor seal performance in service. The system is to provide early warning of seal deterioration to allow appropriate remedial action to be taken.

6.5.5 Swivels and sections in the swivel stack are to use seal arrangements which shall provide redundancy such that leaks can be detected before process fluid release occurs.

6.5.6 The seal fluid pressure is to be higher than the maximum well shut-in pressure and system surge pressure.

6.5.7 A continuous seal fluid leakage detection system is to be monitored to verify system availability and ensure hydrocarbons are not released. The system is to be fitted with alarms to detect early seal deterioration and allow appropriate remedial action to be taken.

6.5.8 In the event of a secondary seal failure, a production ESD is to be initiated and the leak detection system must be capable of precisely identifying the failed seal.

6.5.9 The supply of barrier seal oil for the swivel stack is to be from a dedicated HPU package with its own control panel and feedback to the main control room.

6.5.10 The seal seats and travelling surfaces should be corrosion-resistant and of sufficient hardness to prevent excessive abrasion and wear.

6.5.11 Care is to be taken to minimise the risk of explosive decompression of seal in the event of a catastrophic failure. Maximum decompression rates for the seal material are to be provided by the manufacturer.

6.5.12 Prevention of contamination to dynamic seals is crucial. Seals are to be fitted with a silt-barrier system to prevent sand or particles getting into the seals, where applicable.

6.6 Bolted joints

6.6.1 An acceptable method for the determination of flanged bolt loads is to be found in *Verein Deutscher Ingenieure (VDI) 2230 – Systematic Calculation of High Duty Bolted Joints*. Other suitable internationally recognised Codes or Standards may be used.

6.6.2 For joints subject to fatigue loading, the bolts are to be of ISO 898/1 Material Grade 8.8, 10.9 or 12.9, or equivalent. They are to be pretensioned by a controlled means to 70 to 90 per cent of their yield stress. For bolt sizes greater than M30, pre-tensioning must be carried out, in a rational order, by a hydraulic tensioning device.

6.6.3 The torque on all bolting on bearing housing, support structures and attachments is to be regularly inspected and checked. The maintenance plan is to be submitted to LR for review.

6.7 Swivel stack

6.7.1 The swivel stack is to be designed for the maximum combined operating forces, moments, internal pressures and thermal loading.

6.7.2 In general, the swivel stack is to be analysed by a three-dimensional finite element method unless agreed otherwise with LR. Design calculations, including details of the model, are to be submitted.

6.7.3 Permissible stress levels are to be in accordance with a recognised Code or standard.

6.7.4 Pressure piping attached to the swivel is to comply with *Pt 3, Ch 13, 7 Piping and piping systems*.

6.7.5 Special consideration is to be given to torsional loading effects for the design of universal joints and other connections.

6.7.6 The fluid swivel is to be designed to withstand the maximum range of operating conditions, including maximum well shut-in pressure and pressure surge condition.

6.7.7 Torque arms are to be designed to the appropriate load cases in accordance with *Pt 4, Ch 3 Structural Design*.

6.8 Survey

6.8.1 Joint structures are to be included in the Periodical Classification Surveys, in accordance with the requirements contained in *Pt 1 REGULATIONS*.

6.8.2 A comprehensive surveillance program, including detailed seal replacement and overhaul procedures, is to be developed by the Owner. A sufficient number of spare parts and required tools is to be provided for the installation.

■ *Section 7*
Piping and piping systems

7.1 Plans and particulars

7.1.1 Plans and particulars showing arrangement of oil and gas transport systems, marine machinery and piping for equipment listed in 1.5, are to be submitted in triplicate for approval.

7.2 General requirements for piping systems

7.2.1 Pipes, valves and fittings are to be constructed of steel or other approved materials suitable for the intended service. Where applicable, the materials are to comply with the requirements of *Pt 5, Ch 12 Piping Design Requirements*, or an acceptable Standard or Code.

7.2.2 Piping systems for the oil storage or process transport systems are, in general, to be separate and distinct from marine and utility piping systems essential to the safety of the unit. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

7.2.3 The oil process transport piping systems, piping and fittings forming parts of such systems are to comply with Chapter 8. For units with oil storage tanks, the requirements of *Pt 5, Ch 15 Piping Systems For Oil Storage Tanks* are applicable.

7.2.4 The marine and utility piping systems, piping and fittings forming parts of such systems are to comply with *Pt 5, Ch 12 Piping Design Requirements*, *Pt 5, Ch 13 Bilge and Ballast Piping Systems*, *Pt 5, Ch 14 Machinery Piping Systems* and *Pt 5, Ch 15 Piping Systems For Oil Storage Tanks*, as applicable.

7.2.5 Loading and discharging hoses are to be designed in accordance with acceptable recognised Standards. The selected hose is to be designed and constructed such that it is suitable for its intended purpose, taking into account pressure, temperature, fluid compatibility and mechanical loading, *see also Pt 5, Ch 15, 3.4 Terminal fittings at cargo loading stations* of the Rules for Ships.

7.2.6 Instrument control isolation valves are to be in the locked open position.

7.2.7 Flexible hoses are to comply with the requirements of *Pt 5, Ch 11, 7 Standpipes and branches*of the Rules for Ships.

7.2.8 Where valves of the piping systems are arranged for remote control and are power-operated, a secondary means of operating the valves is to be considered.

7.2.9 Watertight compartments are to be provided with power pump suctions for dealing with their drainage. Special attention is to be given to compartments containing equipment which is essential to the safe operation of the installation. The drainage systems are to comply with the requirements of *Pt 5, Ch 12 Piping Design Requirements*.

■ *Section 8*
Hazardous areas and ventilation

8.1 Plans and particulars

8.1.1 Plans and particulars showing the arrangements of area classification and ventilation systems applicable to the control of hazardous area are to be submitted for approval, as required by *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

8.2 General

8.2.1 For the application of hazardous area classification, *see Pt 7, Ch 2 Hazardous Areas and Ventilation*.

8.2.2 Adequate ventilation is to be provided for all areas and enclosed compartments associated with hazardous fluids. The capacities of the ventilation systems are to comply, where applicable, with the requirements of *Pt 7, Ch 2, 6 Ventilation*, or to an acceptable Code or Standard adapted to suit the marine environment and taking into account any additional requirements which may be necessary during start up of the plant.

■ *Section 9*
Pollution prevention

9.1 General

9.1.1 Sumps and savealls are to be provided at potential spillage points, and drainage systems are to have adequate capacity and be designed for ease of cleaning.

9.1.2 In open areas, arrangements are to be such that oil spillage will be contained, and that suitable drainage and recovery provisions are made that comply with the requirements of National Administration Regulations and any International Convention in force.

■ *Section 10*
Swivel testing requirements

10.1 General

10.1.1 Testing procedure should be specified (and agreed with the Owner/Operator) to ensure that casting, forgings and other items used in the fabrication of the fluid swivel system housing are in accordance with the Rules for Materials.

10.1.2 Seal designs and materials should be Type Approved by dynamic test which simulates a number of years of service under the conditions and with exposure to fluid representative of the design condition and depressurisation. The number of years of successful service to be proven by testing should be agreed with the Owner/Operator.

10.1.3 The following tests are to be performed on each swivel; however, test procedures should be developed by the manufacturers and approved by the Owner/Operator:

(a) Hydrostatic proof test.
(b) Pressure fluctuation test.
(c) Rapid decompression test (Gas Swivel).
(d) Cyclical loading test.

10.1.4 Full rotation tests in each direction and cyclic partial rotation tests should be performed at all operating pressures. Rotation speeds should model real-time conditions to represent accurately the intended application and also to prevent damage to the seals.

10.1.5 Testing is to be conducted in accordance with an approved test procedure in the presence of a Surveyor. The procedure is to address an acceptable leakage rate.

Section

■ *Section 1* General anchor requirements

1.1 General Anchor Requirements

1.1.1 This chapter relates specifically to the following anchor types for floating offshore installations at a fixed location: high holding power (HHP) drag embedment anchors, driven and drilled and grouted pile anchors, suction installed pile/caisson anchors and gravity base anchors. Other anchor types will be specially considered. It also relates to the use of catenary and taut mooring line configurations.

1.1.2 An anchor point is considered to consist of the anchor itself and the chain or mooring line embedded in the seabed.

1.1.3 The anchor design shall be based upon the expected site and seabed conditions at the proposed anchor point locations. The anchor type, dimensions, weight and other characteristics are to be determined by their ability to develop sufficient vertical, lateral and torsional capacity to resist the design loads with appropriate factors of safety based on a working stress design approach; except where stated.

1.1.4 The following information is to be submitted:

- Data, calculations and analysis supporting the selection of anchor.
- Anchor details.
- Proposed test loading or line pull in loads at installation.

and in addition for floating offshore installations at a fixed location:

- Soils data for the anchor locations.

1.1.5 Anchor design using a load and resistance factor design approach will be specially considered.

1.1.6 Consideration could be given to performing special tests, such as centrifuge model tests, to provide a better understanding of anchor behaviour

1.1.7 Installation tolerances on anchor pile orientation and verticality shall be defined during the design process and accounted for in capacity calculations and anchor acceptance.

1.1.8 Consideration is to be given to the anchor installation tolerances on verticality and orientation when designing the connection between the anchor line and the anchor.

1.1.9 The connection between the anchor line and anchor is to be designed so as to minimise disturbance to the seabed soils during pile installation, as this could reduce the axial and lateral resistance provided by the anchor. Any reduction in anchor capacity is to be taken into account.

1.2 Anchor Loads

1.2.1 Geotechnical design shall take account of the nature of the loading placed upon the anchors as defined by *Pt 3, Ch 10 Positional Mooring Systems*.

1.2.2 It should be noted that the static load case, as defined within these rules, contains an element of dynamic loading.

1.2.3 The possible variation in inclination of the applied loading to the foundation is to be taken into account. The envelope of maximum and minimum axial, lateral and torsional loads should be determined based upon the possible range of chain angles, verticality and orientation of the anchor upon installation.

1.2.4 Except for drag anchors, the effective weight of the anchor should be accounted for in the analyses. In general, this should be added to the anchor loads.

1.3 Location control

1.3.1 Sufficient and professional oversight shall be applied to the setup, configuration, verification and acceptance of a vessel's surface and sub-surface positioning systems where used to compute the real-time absolute positions of anchors and locations on the seabed.

1.3.2 Full consideration shall be made to ensure that current operations and procedures, together with all previous survey and site data information, references a single and consistent geodetic datum in terms of spheroid, datum and projection.

1.3.3 Where surface positioning is undertaken using GNSS systems, operations should be undertaken in alignment with IMCA / OGP 015. Alongside tests and checks should be undertaken in port to verify system setup and achievable accuracy at the computational point (e.g. stern roller or crane location.)

1.3.4 Where sub-surface positioning is undertaken using USBL systems, operations should be undertaken in alignment with IMCA / OGP 017. Verification and offshore calibration operations may be required dependent upon installation tolerance.

1.4 Allowable Anchor Point Movements and Line Slack

1.4.1 Estimated values of anchor point movements in service are to be submitted together with the basis and details of the calculations made. These estimates are to account for the difference between any installation test load or mooring line pull-in load and the loading the anchor may be subjected to in-service.

1.4.2 The anchor points are to be so designed that their movements remain within tolerable limits. Where applicable other factors such as the effect of reservoir subsidence and post-seismic induced settlement should be considered.

1.4.3 The potential for the introduction of mooring line slack to the system (from chain cut in during storm loading for example) should be considered. Where applicable, estimates should be made of the amount of slack generated and checks performed to ensure the estimated slack can be accommodated by the mooring system.

1.4.4 The definition of tolerable limits on anchor point movement is to take into account factors such as allowable line slack, mooring line angle at fairlead, ability to remove line slack in-service, proximity to other subsea infrastructure, effect on other connected infrastructure such as risers. Other factors may also affect the definition of tolerable limits on anchor point movement.

1.5 General Anchor Structural Requirements

1.5.1 Structural strength of the anchors is to be checked for intact, damaged and installation cases in accordance with *Pt 3, Ch 10 Positional Mooring Systems* or a recognised structural design code. Where necessary a detailed finite element stress analysis is to be carried out.

1.5.2 A fatigue damage assessment shall be performed for both the anchor and connection between the anchor line and anchor taking into account stress ranges due to environmental loading. Particular attention should be given to any stiffening arrangement of the connection between the anchor line and pile.

1.5.3 For driven anchor piles the effects of driving shall be taken into account in the fatigue damage assessment.

1.6 General Geotechnical Requirements

1.6.1 The geotechnical design of anchors should follow the requirements within these rules and can be performed in accordance with industry recognised methods such as those contained within the latest revision of API RP 2SK, ISO 19901-7 or a similar internationally recognised standard.

1.6.2 Analysis of the anchor/soil interaction under design loading is to take account of the non-linear stress/strain behaviour of the foundation soils, stress history and cyclic loading effects on soil resistance.

1.7 Scour and Erosion

1.7.1 The influence of erosion of soils from around and beneath the anchor is to be taken into account in its design. Erosion due to the following causes is to be investigated:

- The effect of waves and currents passing over the seabed at velocities sufficient to dislodge and transport particles of bed materials (scour and sand waves)
- The relief of hydraulic pressures and pore water pressures built up under the foundation due to environmental loading, which may cause the removal of soil from beneath the foundation (sub-surface erosion or piping).
- The effect of interaction between the mooring line and the seabed, for example trenching caused by buried chain around suction anchors.

1.7.2 As per ISO 19901-4, scour is generally considered to constitute global and local components and seabed level change.

Where appropriate these parameters should be defined. Once these parameters are defined they should be considered within the definition of scour inspection frequency periods, acceptance criteria and trigger points for remedial action.

1.7.3 The methods proposed, for the prevention of and/or protection against erosion, are to be submitted for approval. Options for scour protection include skirts, rock dump, grout bags and frond mats.

1.7.4 Any erosion protection system laid on the seabed is to be designed that it will permit free dissipation of pore water pressures that may be generated in the surface soil under cyclic loading conditions.

1.8 Slope Stability

1.8.1 Where the anchor point is located on or near a slope, the influence of the slope on the anchor is to be considered.

1.8.2 The possibility failure of the slope due to wave or earthquake loading is to be investigated.

1.8.3 The results of any calculations or tests are to be submitted.

1.9 Earthquake

1.9.1 Where appropriate, the influence of earthquake loading on the anchor point stability is to be fully accounted for in the design in relation to the particular site conditions. This assessment is to consider the site response, potential for seismic liquefaction and any other aspects that may influence anchor points such as slope stability.

1.9.2 Where appropriate, the possibility of post-seismic induced settlement and its magnitude should be accounted for during anchor design/selection.

1.9.3 Seismic design and seismic criteria should be considered in accordance with the latest revision of ISO19901-2.

1.10 Unconventional Soil

1.10.1 The site investigation and subsequent design should take into account the presence of unconventional soils, such as those listed in ISO19901-8. It should be recognised that design methods that have been developed and used for design of offshore anchors in conventional soils may not be applicable to unconventional soils and that further investigation and testing may be required. Anchor design for unconventional soils will require special consideration.

■ *Section 2*
Guidelines for site investigation

2.1 General site investigation requirements

2.1.1 The methods of investigation are to be adequate to give reliable information for anchor design and should take account of, but not limited to, the following:

- Nature and stability of the seabed.
- Geomorphology and engineering properties of the strata underlying the seabed.

- Seabed topography in sufficient detail for the type of anchor point being installed.
- Presence of sand waves, ripples & other mobile seabed features.
- Surface deposits, rock outcrops and debris.
- Variations in soil conditions at the anchor point locations.
- Stability of sloping seabeds and other geohazards.
- Natural eruptions and erosion of the seabed due to emissions of gas, mud, fresh water springs etc.
- Presence of shallow gas.
- Other seabed infrastructure.
- Obstructions (manmade or otherwise).

2.1.3 The extent of investigations is to be sufficient in area, depth and detail to adequately cover the anchor design. The site and complexity of the proposed anchor point arrangements and the anticipated seabed soil conditions to be encountered at the anchor point locations are to be considered in determining the extent.

2.1.4 Site investigation is to consist of the following phases:

- Desk study.
- Geophysical site investigation.
- Geotechnical site investigation.
- Integration of geophysical and geotechnical data including update of desk study.
- Determination of design parameters.

2.1.5 Where necessary, site investigation phases are to be updated or repeated to ensure sufficient data is available for anchor design.

2.2 Desk Study

2.2.1 The desk study is to be performed prior to commencing other forms of site investigation. In offshore areas where detailed geological data already exist, this information is to be obtained and used to aid determination of the scope and method of site survey.

2.2.2 The desk study should also consider other anchors or structures that have been installed nearby and take account of information such as installation records or scour inspection reports.

2.3 Geophysical Site Investigation

2.3.1 In absence of a geophysical site investigation standard published by ISO, other good industry practice such as that published by the ISSMGE is to be taken into account when planning and implementing geophysical surveys.

2.3.2 The geophysical survey is generally to be performed over an area centred on the proposed floating installation location. The number and spacing of survey lines are to be appropriate for the site characteristics and type and number of anchor points.

2.4 Geotechnical Site Investigation

2.4.1 The geotechnical site investigation should be performed in accordance with the requirements of ISO 19901-8. Geotechnical site investigation data is considered to comprise of sample data & associated laboratory testing and in situ test data that has been appropriately interpreted.

2.4.2 Geotechnical site investigation data is required at each anchor point location and the geotechnical data shall be sufficient to characterise each soil strata found across the site. Where site conditions are geotechnically uniform a reduced amount of geotechnical investigation locations may be justified at an anchor point cluster. Such a reduction in geotechnical site investigation data is to be supported by proper integration of the geophysical and geotechnical data.

2.4.3 Geotechnical site investigation should extend to a depth greater than the maximum anticipated depth of influence of the anchor.

2.4.4 More than one geotechnical site investigation location for a gravity base anchor may be required where the soil conditions are variable. For gravity base anchors at least one geotechnical site investigation location should extend to a depth greater than the maximum anticipated lateral dimension of the proposed gravity base. This deeper data may be supplemented by shallower data to provide an understanding of soil variability across the gravity base footprint.

2.4.5 When planning a site investigation and selecting equipment, particular consideration should be given to issues that may affect the likely anchor type(s). For example, particular attention should be given to identifying any thin weak strata which may be critical to sliding capacity of gravity anchors, but of relatively little significance to the design of friction piles.

2.4.6 The depth accuracy class, defined according to ISO 19901-8, should be selected to be appropriate for the anchor type. Some anchor types, such as a skirted gravity base, may be particularly sensitive to differences in depth of soil strata. In general this should mean a depth accuracy class of Z3, or better (i.e. Z1 or Z2), shall apply.

2.4.7 The sample class, as described in ISO 19901-8, should be appropriate for the anchor type and design requirements. In general this should mean Class 3 samples, or better (i.e. Class 1 or Class 2), are obtained.

2.5 In situ testing

2.5.1 In situ testing is to be performed in accordance with ISO 19901-8.

2.5.2 For in situ tests (such as cone penetration tests or field vane tests) the Application Class is to be determined based on the anchor type and site conditions anticipated from the desk study.

2.6 Interpretation of site investigation

2.6.1 The results of the geotechnical investigation are to be interpreted and presented to allow understanding of soil and seabed conditions across the site. If less than one geotechnical investigation location per anchor is supplied then the interpretive report shall include justification for this on the basis of the desk study, geophysical data and geotechnical data.

2.7 Unconventional soils

2.7.1 Site investigation in unconventional soils will require special consideration.

■ *Section 3*
General installation requirements

3.1 General installation requirements

3.1.1 Details of the proposed method of anchor and anchor line installation are to be submitted.

3.1.2 Except where stated, anchors are not required to be test loaded at installation. However, for catenary mooring systems preloading of the anchor line is to be performed to ensure its alignment through the seabed and to minimise in-service anchor line slack.

3.1.3 Visual surveys of the seabed are to be performed at the proposed anchor point locations immediately prior to installation. The visual survey should provide confirmation that the anchor point locations and immediate surrounding area are free of any other seabed obstacles or obstructions that may have appeared in the period since the geophysical survey was performed.

3.1.4 Design installation tolerances shall be included in the installation philosophy and where tolerances are not met further confirmation of anchor suitability should be provided. Anchor approval shall be based upon demonstration that the anchors remain suitable.

■ *Section 4*
Mooring line requirements

4.1 Inverse Catenary Analyses

4.1.1 Analyses should be performed using upper and lower bound soil conditions to determine mooring line inverse catenaries in the soil. These will provide the maximum and minimum expected mooring line angle at the anchor padeye.

4.1.2 The calculated range of inverse catenaries should be assessed to demonstrate that the worst case anchor loading has been considered.

4.2 Mooring Line Preload

4.2.1 For anchor types not required to be test loaded at installation it is necessary to perform mooring line pull-in at installation to prevent unacceptable mooring line slack due to inverse catenary cut in during storm conditions.

4.2.2 Details of intended line pull in procedure and load magnitude and any supporting calculations are to be submitted.

■ *Section 5*
Drag embedment anchors – General

5.1 General Requirements

5.1.1 All drag embedment anchors are required to be test loaded at installation to eliminate slack from the grounded section of the mooring lines and to ensure that the mooring line's inverse catenary is set; limiting unacceptable mooring line slack in-service; to detect damage to mooring components and to provide assurance of the anchors holding capacity. Anchor installation test load procedures are set out in *Pt 3, Ch 14, 5.6 Specific Installation Test Load Requirements*.

5.1.2 Appropriate fluke-shank angle should be selected for the soils at the anchor location during the anchor point design phase. It should be ensured that any ballast material included in hollow anchor flukes does not impact on anchors ability to penetrate the seabed.

5.1.3 It should be noted that limited uplift resistance can be provided by some drag anchors, particularly at shallow seabed penetrations. Mooring systems should be designed to prevent uplift occurring at the anchor or it should be demonstrated that the anchor can provide sufficient vertical load resistance at the intended location.

5.2 Drag embedment anchors – Structural aspects

5.2.1 This sub-Section, and *Pt 3, Ch 14, 5.3 Drag embedment anchors – Holding capacity*, apply to drag embedment anchors of high holding power type. Proposals for the use of other anchor types will be specially considered.

5.2.2 Anchors are to be of an approved type.

5.2.3 Material selection for drag embedment anchors are, generally, to be in accordance with *Pt 4, Ch 2, 4 Steel grades*, taking the structural category as 'Primary'.

5.2.4 Supporting calculations to verify the structural strength of the anchor for design service loads and for proof test loads are to be submitted.

5.2.5 The anchors are to be manufactured in accordance with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

5.2.6 Anchors are to be subject to proof test loading in the manner laid down in the Rules. The level of proof test loading for positional mooring anchors is 50 per cent of the minimum rated breaking strength of the attached anchor line.

5.2.7 Proof load testing of large fabricated anchors (in excess of 15 tonnes mass) may be waived for classification, subject to the following:

(a) Structural strength of anchor type being verified by finite element analysis procedure.
(b) All main structural welds being subject to non- destructive examination as follows at manufacture:

- 100 per cent visual.
- 100 per cent MPI.
- 100 per cent UT/radiographic, for full penetration welds.

5.2.8 Not withstanding the above, attention is drawn to the separate requirement of some National Authorities for proof load testing of anchors.

5.3 Drag embedment anchors – Holding capacity

5.3.1 The requirements of *Pt 3, Ch 14, 5.2 Drag embedment anchors – Structural aspects* are also to be considered, in addition to this sub-Section.

5.3.2 Factors of safety for anchor holding capacity for floating offshore installations at a fixed location are not to be less than the values given in *Pt 3, Ch 14, 5.3 Drag embedment anchors – Holding capacity 5.3.2*. Anchors for positional mooring of mobile offshore units are to be sufficient in number and holding capacity for the intended service. It is the Owner's/Operator's responsibility to ensure adequate anchor holding capacity for each location or holding ground.

Table 14.5.1 Factors of safety for anchor holding capacity for floating offshore installations at a fixed location

Design case	Anchor load case	Factor of safety
Intact	Static load, see Note 1	2,0
Intact	Dynamic load, see Note 1	1,5
Damaged	Dynamic load	1,15

NOTES

1. Static load refers to steady plus low frequency load components. Dynamic load refers to static plus wave frequency components of loading.

2. Increased factors of safety will require to be applied where the data supporting the anchor selection is not considered adequate in a particular case.

3. Where the use of vertically loaded anchors (VLAs) is proposed, for soft soil areas, special consideration will be given to required factors of safety.

5.4 Drag Anchors - Acceptable Design Methods

5.4.1 For drag anchors, the ultimate holding capacity, penetration and drag are to be based on empirical design data for the specific type of anchor under consideration. The soil conditions at the anchor location and previous experience in similar soil conditions with the specific type of anchor are to be considered.

5.4.2 Particular consideration is to be given to locations with layered soil conditions and their effect on ultimate holding capacity, penetration and drag.

5.4.3 Anchor sizing charts should be used with caution. Special care should be taken where soil conditions at the intended anchor location differ from those presented in available sizing charts, for example many sizing charts contain no provision for a layered seabed or calcareous soils.

5.4.4 The use of analytical design methods or numerical analysis to predict drag anchor holding capacity, penetration and drag will be considered as a supplement to *Pt 3, Ch 14, 5.4 Drag Anchors - Acceptable Design Methods*, provided that the methods have been calibrated to actual anchor behaviour.

5.5 Anchor Trajectory Prediction

5.5.1 Expected drag anchor trajectory during installation should be submitted to LR for review. This should include expected depth of anchor fluke tip and attitude at the completion of installation activities. This prediction is of particular importance when considering the effects of scour or layered soils.

5.5.2 Final anchor position after completion of test load should be inspected and recorded/estimated based on expected chain catenary and submitted to LR. Alternatively anchor position may be directly measured using a monitoring device.

5.6 Specific Installation Test Load Requirements

5.6.1 All drag anchors are required to be test loaded at installation to the satisfaction of the LR Surveyor. The methodology for monitoring and accepting load applied and anchor drag during the anchor preload period shall be submitted to LR prior to installation. Records of load and drag versus time shall be submitted to LR once anchor installation is complete.

5.6.2 Installation test load magnitude is to be agreed with LR prior to installation, and should take account of cyclic loading, potential for scour, unconventional soil types and any other factors which may adversely affect in service anchor movement. Where the above are not deemed to have a significant effect a test load of not less than 80% of the maximum intact load may be appropriate; however in some circumstances a test load of 100% or more of the intact load may be required to demonstrate required anchor performance. The test load is not, however, to exceed 50% of the minimum breaking strength of the mooring line.

5.6.3 Acceptance of installation test load by attending LR surveyor will be based on assessment of supplied methodology, load achieved, anchor drag and hold period.

5.6.4 The test load is to be held for a period of not less than 20 minutes. During this time no anchor drag should be observed.

Where it is not possible to monitor anchor position directly during the hold period this should be estimated from vessel position and checked post hold period. Visual ROV inspection of expected anchor position is also recommended.

■ *Section 6* Anchor pile

6.1 Design Requirements

6.1.1 Anchor piles are characterised by being relatively long and slender and having a length to diameter ratio or width ratio generally greater than 10.

6.1.2 *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* defines the design cases and factors of safety to be used for anchor piles for a catenary mooring system. *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* defines the design cases and factors of safety for anchor piles for taut-leg mooring system. For anchor pile clusters the group as a whole is to have a factor of safety as required by *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* and *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3*. Individual piles in a group may have lower factors of safety; for taut-leg anchor piles, the minimum factor of safety for individual piles within a group is to be 1.5.

6.1.3 *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* and*Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* do not apply to axial capacity of piles installed by vibrating hammers.

Table 14.6.1 Minimum factors of safety for anchor piles for a catenary mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,0	2,0
Intact	Dynamic load, *see* Note 2	1,5	1,5
Damaged	Dynamic load	1,5	1,5

NOTES

1. Static load refers to steady plus low frequency, components of loading.

2. Dynamic load refers to static plus wave frequency components of loading.

Table 14.6.2 Minimum factors of safety for anchor piles for a taut-leg mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,7	2,0
Intact	Dynamic load, *see* Note 2	2,0	1,5
Damaged	Dynamic load	2,0	1,5

NOTES

1. Static load refers to steady plus low frequency, components of loading.

2. Dynamic load refers to static plus wave frequency components of loading.

6.1.4 The efficiency of the group, that is its capacity compared to the sum of the capacities of individual anchor piles within the group, is to be checked.

6.1.5 Consideration is to be given to the possible formation of a post-hole at the pile head and its effect on capacity.

6.1.6 The influence of pile shoes, internal stiffeners, padeye and any other protrusions should be accounted for within the pile capacity and installation assessments.

6.1.7 For piles subjected to permanent tension loads, consideration is to be given to long term changes in soil stresses around the anchor piles and upward creep.

6.2 Axial capacity

6.2.1 This sub-Section applies to anchor piles that are either driven or drilled and grouted into the seabed. Piles installed by vibrating hammers are not recommended where axial loading is significant.

6.2.2 Other methods, than those contained within API RP 2SK, ISO 19901-7 and associated standard, of determining axial capacity are acceptable, provided they are supported by sufficient evidence of their validity together with appropriate laboratory testing.

6.2.3 For unconventional soils, such as carbonate soils, particular attention should be given to ensure that appropriate design methodology is used. This applies to cohesive and non-cohesive soils.

6.2.4 The pile design must satisfy the required factors of safety in *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* and *Pt 3, Ch 14, 6.1 Design Requirements 6.1.3* or pull-out capacity and bearing capacity.

6.2.5 No end bearing should be taken for drilled and grouted piles unless it can be demonstrated that there is no infill at the bottom of the drilled hole, or the calculations account for the compressibility of such infill.

6.2.6 A reduction in axial capacity should be considered where large lateral soil displacements are predicted.

6.2.7 For tension loads, no end bearing (or suction) component at the pile tip is to be considered unless this can be justified based on pile configuration, rate of loading and soil permeability.

6.2.8 Pile capacity in rock is to be specially considered.

6.2.9 Consideration should be given to the effect of close spacing of piles, since the ultimate axial capacity of a group can be less than the sum of the individual capacities. This may be determined by consideration of the group as an 'equivalent pier'.

6.2.10 Appropriate account should be taken of the driving shoe and any other protrusions or add-ons that may affect the internal or external skin friction.

6.2.11 Drilled and grouted pile design will be specially considered.

6.3 Lateral Capacity

6.3.1 For anchor piles, the lateral capacity and pile response are normally to be determined using a beam-column non-linear soil/structure interaction finite element analysis. The non-linear axial and lateral soil resistance/pile deflection is to be modelled using t-z and p-y curves, respectively.

6.3.2 It should be demonstrated that the selected p-y curve methods are valid for the soil conditions at the site. For unconventional soil conditions consideration should be given to other p-y curve methods specifically developed for those soil types (see guidance note).

6.4 Installation – Driven Piles

6.4.1 Driving stresses and static stresses due to the weight of the hammer are to be considered in the selection of pile driving hammers and pile wall thickness. Driving stresses are also to be included in the assessment of pile fatigue lives. The stresses induced in the pile during driving can be estimated using a wave equation analyses.

6.4.2 Any effects resulting from the use of a pile guide frame should be considered within the pile design. This may include consideration of disturbance caused during frame installation and removal.

6.4.3 A full record of the anchor pile driving operation is to be kept; and is to be submitted to LR. The records of the anchor pile driving operation should include the following details:

- Timing of the various operations

- Hammer characteristics (stroke and any measurements of striking energy and energy transmitted to the pile head) and blowcount with penetration
- Configuration of the top of the pile giving the cushion and anvil materials together with primary dimensions
- State of cushion (number of blows suffered and physical appearance) at the start of driving and time(s) at which the cushion is changed.
- Soil plug measurement on completion of driving

6.5 Installation – Drilled & Grouted Piles

6.5.1 The methods for drilling and grouting and details of the plant and materials are to be submitted to LR for approval.

6.5.2 The construction programme is to avoid leaving holes open for long periods in soils or rock sensitive to exposure to water or drilling fluids.

6.5.3 A specimen record is to be submitted for approval prior to the installation of the first pile.

6.5.4 A full record of the drilling and grouting operation is to be submitted to LR and should include the following details:

- Timing of the various operations.
- Method of drilling.
- Density, viscosity, flow rate and pressure of drilling fluid during drilling.
- Description of returns, if any, from the borings.
- Bit pressure, torque and speed of drilling tools.
- Details of circulation loss and any remedies adopted.
- Hole survey details (the profile and linearity of all holes are to be surveyed to their full depth).
- Details of checks made to determine the existence of any material which has fallen into the hole prior to grouting.
- Final position of any reinforcement or insert piles placed.
- Fluid pressure maintained during drilling and grouting.
- Details of the density, flow rates, grout level and pressure of grout during pumping and total volume of grout pumped (means of monitoring should be specified)
- Details of grout mix design and its constituent materials.
- Programme of grout sampling and testing, including measurements of density and grout crushing strength at 1, 2, 7 and 28 days.
- Grout return level check on completion and grout slump level check at least 12hours after completion. These grout level checks should be provided relative to seabed.

■ *Section 7*
Suction installed piles

7.1 Design Requirements

7.1.1 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of suction anchor piles. The installation tolerances are to be considered when assessing failure modes for the soil.

7.1.2 Consideration should be given to internal soil plug heave.

7.1.3 Particular consideration should be given to the effect of layered soils on installation.

7.1.4 The effect of any jetting system or similar installation aids is to be assessed.

7.2 Acceptable basis for suction installed pile design

7.2.1 Suction piles should be designed in accordance with industry recognised practice such as ISO 19901-7.

7.2.2 Suction piles are characterised by having a large diameter and a length to diameter ratio generally less than eight, and are essentially caisson-type foundations if the length to diameter ratio is less than three.

7.2.3 Table 14.7.1 defines the design cases and factors of safety to be used for suction anchor piles for a catenary mooring system. Table 14.7.2 defines the design cases and factors of safety to be used for suction anchor piles for a taut-leg mooring

system. The axial and lateral factors of safety for suction piles should be accounted for within in the analyses as described within ISO 19901-7 taking account of whether axial loading, lateral loading or combined axial-lateral loading controls the anchor design.

Table 14.7.1 Minimum factors of safety for suction anchor piles for a catenary mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,0	2,0
Intact	Dynamic load, *see* Note 2	1,5	1,5
Damaged	Dynamic load	1,5	1,5

NOTES

1.Static load refers to steady plus low frequency components of loading.

2.Dynamic load refers to static plus wave frequency components of loading.

Table 14.7.2 Minimum factors of safety for anchor piles for a taut-leg mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,7	2,0
Intact	Dynamic load, *see* Note 2	2,0	1,5
Damaged	Dynamic load	2,0	1,5

NOTES

1. Static load refers to steady plus low frequency, components of loading.

2. Dynamic load refers to static plus wave frequency components of loading.

7.2.4 Suction anchor pile analysis is generally performed using either a continuum finite element model or a limit plasticity model of the pile and soil in order to assess appropriate failure modes. Pile response and the determination of soil reaction stresses for structural analysis of the suction anchor pile are to be analysed using non-linear soil/structure interaction finite element analyses.

7.2.5 The influence of pile shoes, internal stiffeners, padeye and any other protrusions should be accounted for within the pile capacity and installation assessments.

7.2.6 For suction anchor piles subjected to permanent tension loads, consideration is to be given to long term changes to soil stresses around the suction anchor pile and upward creep.

7.2.7 For tension loads, no end bearing (or suction) component at the pile tip is to be considered unless this can be justified based on pile configuration, rate of loading and soil permeability.

7.2.8 Consideration is to be given to the possible formation of a post-hole at the pile head and its effect on capacity

7.3 Installation of suction piles

7.3.1 Soil resistance to suction anchor piles is to be determined. The potential for internal soil heave and soil plug failure during installation is to be considered.

7.3.2 The record of installation of piles installed by suction is to be submitted to LR and should include

- Pile penetration
- Pressure differential
- Orientation
- Verticality

■ *Section 8*
Gravity anchors

8.1 General gravity anchor requirements

8.1.1 Gravity bases should be designed in accordance with industry recognised practice such as ISO 19903 and ISO 19901-4.

8.1.2 A material factor for soil of 1,25 is to be applied to the design undrained shear strength, tangent of the angle of internal friction of the soil and tangent of the angle of interface friction between the soil and the gravity anchor.

8.1.3 Appropriate load coefficients will be specially considered for particular applications for catenary and taut-leg mooring systems.

8.1.4 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of gravity anchors. The installation tolerances are to be taken into account when assessing failure modes for the soil.

8.1.5 The stability and characteristics of any ballast will require special consideration. In particular the ballast should be capable of withstanding cyclic loading.

8.1.6 The gravity anchor is to have sufficient strength to account for the stresses due to the applied loading conditions.

8.1.7 Wave loads on the seabed are to be considered when such loads are unfavourable to stability.

8.2 Foundation movements

8.2.1 Calculations of foundation movements are to include the effects of short-term and long-term loading.

8.2.2 The following possible causes of vertical movements are to be investigated:

- Immediate settlement
- Secondary settlement due to steady, or permanent, loading
- Long-term consolidation and settlement due to dynamic, static and steady loading.
- Recoverable displacements due to transient loading.

8.2.3 Particular account is to be taken of the possibility of differential settlement due to variations in soil conditions over the foundation base area.

8.2.4 The extent of horizontal movements and tilt are to be assessed. The relative magnitudes of recoverable and non-recoverable displacement are to be determined.

8.3 Foundation Contact Pressure

8.3.1 Complete contact with the seabed is to be maintained at all times and the stresses imposed by the foundations on the seabed are to be compressive under all loading conditions.

8.3.2 Calculations of the local contact stresses between the foundation and the seabed are to take into account the results of the seabed survey.

8.3.3 Local soil reactions on gravity foundations are to be based on the highest expected values of soil strength in the upper soil layers.

8.3.4 Unless specifically considered in the design, any voids remaining beneath the foundation after installations are to be filled with cementitious grout (for example).

8.4 Seabed penetrating elements

8.4.1 Where foundations have skirts, dowels or other seabed penetrating elements which transfer load to the seabed, the effect of these components is to be taken into account when determining the efficiency of, and loads in, the foundations for bearing capacity and sliding resistance. These items are to be designed as structural members.

8.4.2 The resistance of skirts, dowels and other seabed penetrating elements to penetration of the seabed during installation of the foundation and their effect, if any, on water flow beneath the foundation during installation is to be taken into account in the design calculations.

8.4.3 The penetration resistance of elements such as skirts and dowels is to be based on conservative (upper bound) estimates of soil strength. Also, by considering more typical penetration resistances, account may be taken of the foundation in formulating possible eccentric ballasting requirements.

8.4.4 The gravity base anchor installation should ensure that any skirts or other seabed penetrating elements penetrate as required by the design.

8.4.5 Provision is to be made for the relief of water pressure generated within the skirts during installation of the structure.

8.5 Installation of gravity anchor foundations

8.5.1 The positioning of the foundation is to be properly related to the location of the site investigation.

8.5.2 Any significant obstructions identified by the seabed survey carried out prior to the installation are to be removed before emplacement.

8.5.3 Differential ballasting may be required to accommodate non-uniform soil properties or a sloping seabed. In general, reduction of pressure beneath the foundation is not to be used to aid installation, unless it can be demonstrated that washout or flow of soil will not occur.

8.5.4 Records of settlement and tilt of the structure are to be made during installation and properly correlated to those required to be kept while the structure is in service.

■ *Section 1* Integrated Software Intensive System – 'ISIS' notation

1.1 General

1.1.1 Integrated Software Intensive System class notation **ISIS** may be assigned where an integrated computer system in compliance with *Pt 6, Ch 1, 6 Integrated computer control - ICC notation* of the *Rules and Regulations for the Classification of Ships, July 2016* provides fault tolerant control and monitoring functions for systems that are critical to safety or operational performance. Identification of the Integrated and Software Intensive Systems are to be derived using a risk assessment technique to a recognised National or International Standard, such as those detailed in IEC/ ISO 31010 Risk Management – Risk Assessment techniques. Examples of such systems are listed but not limited to the following:-

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.
- Well control system.
- Pollution control system.
- Jacking system for self-elevating unit.
- Cantilever skidding system for drilling unit.
- Power Management System (PMS).
- Zone Management Systems (ZMS) (for all equipment where applicable).
- Mud and cement management system.
- HVAC (where applicable).
- Lifting equipment/Load positioning.
- Safety/Emergency systems.
- Communication Systems

1.1.2 Systems are to be considered critical to safety or operational performance when they are either directly or indirectly relied upon to provide services which are critical to continued safety or operational performance (e.g. if a critical system has an electronic control which is cooled by chilled water, then the chilled water system is to also be considered critical, if it has an impact on continued safety or operational performance of the system).

1.1.3 The risk assessment is to demonstrate that suitable risk mitigation has been achieved for all normal and reasonably foreseeable abnormal conditions. The scope of analysis required for each system is defined in *Pt 3, Ch 15, 1.1 General 1.1.3* to *Pt 3, Ch 15, 1.1 General 1.1.4* and in the respective parts of the Rules.

Note A reasonably foreseeable abnormal condition is an event, incident or failure that:

- has happened and could happen again;
- has not happened but is considered possible. Where the likelihood is considered extremely unlikely or the consequences are trivial, and no further prevention or mitigation action is to be taken, then this is to be justified;
- is planned for (e.g., emergency actions cover such a situation, maintenance is undertaken to prevent it.).

  These conditions should be identified by:

- using analysis processes that are capable of revealing abnormal conditions;
- employing a mix of personnel including: designers, operators, persons who carry out maintenance, those with relevant domain knowledge and understanding, and competent safety/risk professionals to apply the processes;
- referencing relevant events and historic data; and documenting the results of the analysis.

1.1.4 The risk assessment required by *Pt 3, Ch 15, 1.1 General 1.1.1* is to:

(a) be organised in terms of systems and functions;
(b) identify the system and sub-systems and their modes of operation and the equipment;
(c) identify potential failure modes, system failures and degraded situations, and their causes;
(d) analyse the effects of failure modes, system failures and degraded situations and determine their impact on safety and operational performance;
(e) specify the mitigation needed to address the risks identified for each failure mode, system failure or degraded situation; in order to maintain safety and operational performance; and
(f) specify trials and testing necessary to demonstrate the identified risks have been mitigated sufficiently to ensure that safety and operational performance will be maintained.

1.2 General requirements

1.2.1 The Integrated Software Intensive System is to comply with the programmable electronic system requirements of *Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements*of the Rules for Ships and the control and monitoring requirements of the Rules applicable to a particular equipment, machinery or systems.

1.2.2 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.7* of the Rules for Ships.

1.3 Programmable electronic systems – Additional requirements for integrated systems

1.3.1 The requirements of *Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems 2.14.2* of the Rules for Ships apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or ship safety functions, *see Pt 6, Ch 2, 17 Fire safety systems* of the Rules for Ships.

1.3.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for the systems identified by *Pt 3, Ch 15, 1.1 General 1.1.1*

1.3.3 The system requirements specification, *see Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.5* of the Rules for Ships, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

1.3.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

1.3.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew, and ship safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see Pt 6, Ch 1, 2.4 Safety systems, general requirements 2.4.6* and *Pt 6, Ch 1, 2.5 Control systems, general requirements 2.5.4* of the Rules for Ships, and that the operability of the systems derived from the process required by *Pt 3, Ch 15, 1.1 General 1.1.1*, will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

1.3.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

1.3.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g., the selection of a particular screen page or mode of operation. *See also Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.16* of the Rules for Ships.

1.4 Operator stations

1.4.1 The requirements for the operator stations are given in *Pt 6, Ch 1, 6.3 Operator stations* of the Rules for Ships, which are to be complied with.

1.4.2 Additions or amendments to these requirements are given in 6.3.3.

1.4.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g., in control, standby, etc.) is to be clearly indicated, *see also* 2.2.

■ *Section 2*
Systems engineering principles

2.1 General – Scope and objectives

2.1.1 The requirements of this Section aim to ensure that risks to offshore safety and the environment, stemming from the introduction of integrated software intensive systems, are addressed insofar as they affect the objectives of classification. Hereafter, integrated software intensive system includes all systems listed in *Pt 3, Ch 15, 1.1 General*.

2.1.2 The requirements of this Section are to be satisfied where an integrated software intensive systems is required to be developed, constructed, installed, integrated and tested in accordance with LR's Rules and Regulations and for which the corresponding machinery class notation is to be assigned, *see Pt 1, Ch 2, 2.5 Class notations (machinery)*.

2.1.3 It is to be noted that as well as the requirements of this Section, the general requirements of LR's Rules and Regulations are also to be satisfied as far as they are applicable.

2.1.4 Compliance with ISO 15288 *Systems and Software Engineering – System Life Cycle Processes* or an acceptable equivalent National Standard may be accepted as meeting the requirements of *Pt 6, Ch 1, 2.3 Alarm systems, general requirements* of the Rules for Ships.

2.2 Information to be submitted

2.2.1 The information described in 2.2.2 and 2.2.3 is to be submitted for consideration.

2.2.2 General description detailing the extent of the integrated software intensive system, the offshore unit services it is to provide, its operating principles, and its functionality and capability when operating in the environment to which it is likely to be exposed under both normal and foreseeable abnormal conditions. The general description is to be supported by the following information as applicable:

(a) System block diagram.
(b) Piping and instrumentation diagrams, communication networks.
(c) Description of operating modes, including:

    start-up;
    shut-down;
    automatic:
    reversionary;
    manual, and
    emergency.

(d) Description of safety related arrangements, including:

    safeguards;
    automatic safety systems; and

interfaces with offshore units safety systems.

(e) Description of connections to other offshore unit machinery, equipment and systems, including:

electrical;
mechanical;
fluids;
automation;
communication network; and
protocols of the network.

(f) Plans of physical arrangements, including:

location;
operational access; and
maintenance access.

(g) Operating manuals, including:

instructions for start-up;
operation;
shut-down and emergency;
instructions and frequency for maintenance;
instructions for adjustments to the performance;
parameters and functionality; and
details of risk mitigation arrangements.

(h) Maintenance manuals, including:

Instructions for routine maintenance or repair following failure.
Instructions for software configuration management such as upgrading and modification.
Disposal of components and recommended spares inventory.

2.2.3 Project process documentation including:

(a) Project management plan, *see* 2.3.
(b) Quality assurance plan, *see* 2.4.
(c) Risk management plan, *see* 2.5.
(d) Configuration management plan, *see* 2.6.
(e) Requirements definition document, *see* 2.9.
(f) Design definition document, *see* 2.8.
(g) Implementation plan, *see* 2.9.
(h) Integration plan, *see* 2.10.
(i) Verification plan, *see* 2.11.
(j) Validation plan, certification and survey, *see* 2.12.

2.3 Project management

2.3.1 A project management procedure is to be established in order to define and manage the key project processes. The project processes are to include the those described in *Pt 6, Ch 1, 2.4 Safety systems, general requirements* of the Rules for Ships.

2.3.2 For the entire project, and each of the processes within the project, the project management procedure is to define the following:

(a) Activities to be carried out.
(b) Required inputs and outputs.
(c) Roles of key personnel.
(d) Responsibilities of key personnel.
(e) Competence of key personnel.
(f) Schedules for the activities.

(g) Roles and responsibilities of stakeholders including Owner, Operator, Shipyard, System Integrator, Supplier or Subcontractor for each required activity of project processes from 2.3 to 2.12.

2.4 Quality assurance

2.4.1 A quality assurance procedure is to be established in order to ensure that the quality of the integrated software intensive system is in accordance with a defined quality management system that is acceptable to LR.

2.4.2 The procedure is to define the specific quality controls to be applied during the project in order to satisfy the requirements of the quality management system.

2.4.3 The quality management system is to satisfy the requirements of ISO 9001 *Quality management systems*. Requirements and software development is to satisfy the requirements of ISO 90003 *Software engineering – Guidelines for the application of ISO 9001 to computer software*, or other equivalent acceptable National Standard.

2.5 Risk management

2.5.1 A risk management procedure is to be established in order to ensure that any risks stemming from the introduction of the integrated software intensive system are addressed, in particular risks affecting:

(a) The structural strength and integrity of the offshore unit's hull.
(b) The safety of integrated software intensive system onboard of the offshore unit.
(c) The safety of crew.
(d) The reliability of the systems identified by *Pt 3, Ch 15, 1.1 General 1.1.1* and emergency systems.
(e) The environment.
(f) Offshore drilling operations with introduction of integrated software intensive systems.

2.5.2 The procedure is to consider the hazards associated with development, integration, installation, operation, maintenance and disposal, both with the integrated software intensive system functioning correctly and following any reasonably foreseeable failure.

2.5.3 The procedure is to take account of stakeholder requirements, *see Pt 3, Ch 15, 2.7 Requirements definition*.

2.5.4 The procedure is to take account of design requirements, *see Pt 3, Ch 15, 2.8 Design definition*.

2.5.5 The procedure is to ensure that hazards are identified using acceptable and recognised hazard identification techniques, *see Pt 3, Ch 15, 2.5 Risk management* to 2.5.14, and that the effects of the following influences are considered:

(a) Offshore unit operations, including:

Underway, manoeuvring, pilotage, docking, alongside and maintenance, jacking or dynamic positioning, well drilling, well completion, well control, training exercises, emergency abandon, commissioning and trials.

(b) Offshore unit conditions under normal and reasonably foreseeable abnormal operating conditions arising from failures or misuse of equipment or systems onboard of offshore unit, including:

Normal operation, blackout, loss of position, fire in a single compartment, explosion in a single compartment and flooding of a single compartment.

(c) Configuration and modes of operation provided for the intended control of integrated software intensive system, including:

Start-up, running, shut-down, automatic, reversionary, manual and emergency.

(d) Environmental conditions, including:

Temperature, pressure, humidity, water spray, salt mist, vibration, shock, inclination, vocanic activities, seabed conditions, hurricane or storm, subsea acoustic noise, electrical fields and magnetic fields.

(e) Dependencies, including:

Power, fuel, air, cooling, heating, mud, cement, data, and human input.

(f) Environmental impact of the offshore unit throughout its lifecycle, including:

Emissions to air, discharges to water, noise and waste products.

(g) Failures, including:

Human error, supply failure, system, software, communication network, machinery, equipment and component failure, random, systematic and common cause failures.

2.5.6 The procedure is to ensure that risks are analysed using acceptable and recognised Risk Based Analysis techniques, *see* 2.5.9 to 2.5.14, and that the following effects are considered:

(a) Local effects: Loss of function, component damage, fire, explosion, electric shock, harmful releases and hazardous releases.
(b) End effects on: Loss of services essential to the safety of the offshore unit, services essential to the safety of personnel onboard of offshore unit and services essential to the protection of the environment.

2.5.7 The procedure is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

2.5.8 Details of risks, and the means by which they are mitigated, are to be included in the operating manual, *see Pt 3, Ch 15, 2.2 Information to be submitted*.

2.5.9 Risk Based Analysis (RBA) technique is to be selected from IEC/ISO 31010 *Risk Management – Risk Assessment Techniques*. The technique selected is to be carried out in accordance with the relevant International Standard or applicable National Standard and with 2.5.10 to 2.5.14. A justification is to be provided which demonstrates the suitability of the Standard and analysis technique chosen.

2.5.10 The RBA is to demonstrate that suitable risk mitigation has been achieved for all normal and foreseeable abnormal conditions. The scope of analysis required for each system is defined in 2.5.11 to 2.5.14 and in the respective parts of the Rules.

2.5.11 The RBA is to be organised in terms of items of equipment and function. The effects of item failures or damage at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.5.12 RBA is to:

(a) Identify the equipment or sub-system and their mode of operation;
(b) Identify potential failure modes and damage situations and their causes;
(c) Evaluate the effects on the system of each failure mode and damage situation;
(d) Identify measures for reducing the risks associated with each failure mode;
(e) Identify measures for failure mitigation; and
(f) Identify trials and testing necessary to prove conclusions.

2.5.13 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

2.5.14 Where RBA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than a specific analysis of the software code.

2.6 Configuration management

2.6.1 A configuration management procedure is to be established in order to ensure traceability of the configuration of the integrated software intensive system, its subsystems and its components.

2.6.2 The procedure is to identify items essential for the safety or operation of the integrated software intensive system (configuration control items) which could foreseeably be changed during the lifetime of the integrated software intensive system, including:

(a) Documentation.
(b) Software.
(c) Sensors.
(d) Actuators.
(e) Instrumentation.
(f) Valves.
(g) Pumps.
(h) BOP stacks.

2.6.3 The procedure is to take account of the design requirements, *see Pt 3, Ch 15, 2.8 Design definition*.

2.6.4 The procedure is to include items used to mitigate risks, *see Pt 3, Ch 15, 2.5 Risk management*.

2.6.5 The procedure is to ensure that any changes to configuration control items are:

(a) Identified.
(b) Recorded.
(c) Evaluated.
(d) Approved.
(e) Incorporated.
(f) Verified.

2.6.6 The procedure is to specify the required software testing for any changes to configuration control items for the whole lifecycle of the integrated software intensive system.

2.7 Requirements definition

2.7.1 A requirements definition procedure is to be established in order to define the functional behaviour and performance throughout the whole lifecycle of the integrated software intensive system required by individual stakeholders, in the environments to which the integrated software intensive system is likely to be exposed under both normal and foreseeable emergency conditions.

2.7.2 The procedure is to take account of requirements resulting from key stakeholders, including:

(a) Owner.
(b) Operator.
(c) Crew.
(d) Shipyard.
(e) Systems integrator.
(f) Maintenance personnel.
(g) Surveyors.
(h) Manufacturers and suppliers.
(i) National Administration.
(j) LR.

2.7.3 The procedure is to take account of requirements resulting from the following influences:

(a) Offshore unit operations, *see Pt 3, Ch 15, 2.5 Risk management*).
(b) Ship conditions, *see* 2.5.5(b).
(c) Environmental conditions, *see* 2.5.5(d).
(d) Applicable provisions, including:

    Statutory legislation;
    classification requirements;
    international standards;
    national standards; and
    codes of practice.

(e) Expected users, including:

    Multi-national users with a range of national languages and cultures
    fatigued users;
    users without dedicated training; and
    maintenance and survey personnel.

(f) Design, construction and operational constraints, including:

    Effect of particular design decisions or component choices on other aspects of design, risk and production engineering compromises, verification, integration and validation considerations, maintenance and disposal, and changes in use.

2.7.4 The procedure is to specify the functional behaviour and performance requirements and is to identify the source of the requirements.

2.7.5 The requirements specification is to fully specify, either directly or by reference to other submitted documents, all external interfaces between the software product and other software or hardware.

2.7.6 The procedure is to detail required functions the integrated software intensive system is to perform under both normal and foreseeable abnormal conditions.

2.7.7 The procedure is to define specific boundary conditions of each required function of the integrated software intensive system.

2.7.8 The procedure is to ensure overall integrity of the system requirements through verification and analysis of integrity of sets of requirements.

2.8 Design definition

2.8.1 A design definition procedure is to be established in order to define the requirements for the design of the integrated software intensive system which satisfies stakeholder requirements, quality assurance requirements, risk mitigate requirements and complies with basic internationally recognised design requirements for safety and functionality.

2.8.2 The procedure is to ensure that the design of the integrated software intensive system satisfies:

(a) Statutory legislation.
(b) LR's requirements.
(c) International Standards and Codes of Practice where relevant.

2.8.3 The procedure is to take account of stakeholder requirements, *see* 2.7.

2.8.4 The procedure is to take account of quality assurance requirements, *see Pt 3, Ch 15, 2.4 Quality assurance*.

2.8.5 The procedure is to take account of risk management requirements, *see Pt 3, Ch 15, 2.5 Risk management*.

2.8.6 The procedure is to ensure that the requirements for the design of major components and subsystems of the integrated software intensive system can be verified before and after integration.

2.8.7 The procedure is to specify the design requirements and is to identify the source of the requirements.

2.8.8 Any deviations from stakeholder requirements are to be identified, justified and accepted by the originating stakeholder, communicated to involved stakeholders and documented.

2.9 Implementation

2.9.1 An implementation procedure and technology is to be selected in order to realise specific integrated software intensive system that satisfies the design requirements of the machinery or an engineering system or integrated software intensive system through verification, *see Pt 3, Ch 15, 2.11 Verification* and satisfies stakeholder requirements through validation, *see Pt 3, Ch 15, 2.12 Validation*.

2.9.2 The procedure and technology is to take account of quality assurance requirements, *see* 2.4.

2.9.3 The procedure and technology is to take account of design requirements, *see* 2.8.

2.9.4 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.2* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.7* of the Rules for Ships. Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the manufacturer.

2.9.5 To demonstrate compliance with 2.9.4:

(a) software quality plans and safety evidence are to be submitted for consideration;
(b) an assessment inspection of the manufacturer's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR; and
(c) for software development lifecycle, an evidence of satisfying internationally recognised standards and practices that are acceptable to LR is to submit for consideration of satisfying 2.9.4(b).

2.10 Integration

2.10.1 An integration procedure is to be established in order to ensure that the integrated software intensive system is assembled in a sequence which allows verification of individual system, individual subsystems and major components following integration in advance of validating the entire integrated software intensive system.

2.10.2 The procedure is to take account of the verification requirements, *see* 2.11.

2.10.3 The procedure is to identify the subsystems and major components, the sequence in which they are to be integrated, the points in the project at which integration is to be carried out, and the points in the project at which verification is to be carried out.

2.11 Verification

2.11.1 A verification procedure is to be established in order to ensure that systems, subsystems and major components of the integrated software intensive system satisfy their design requirements.

2.11.2 The procedure is to verify design requirements, *see Pt 3, Ch 15, 2.8 Design definition*.

2.11.3 The procedure is to identify the requirements to be verified, the means by which they are to be verified, the verification methods and techniques, and the points in the project at which verification is to be carried out.

2.11.4 The procedure is to be based on one or a combination of the following activities as appropriate:

(a) Design review.
(b) Product inspection.
(c) Process audit.
(d) Product testing.

2.12 Validation

2.12.1 A validation procedure is to be established in order to ensure the functional behaviour and performance of the integrated software intensive system meets with its functional and performance requirements in its intended operational environment.

2.12.2 The procedure is to validate stakeholder requirements, *see Pt 3, Ch 15, 2.7 Requirements definition*.

2.12.3 The procedure is to validate arrangements required to mitigate risks, *see Pt 3, Ch 15, 2.5 Risk management*.

2.12.4 The procedure is to validate the traceability of the configuration control items, *see Pt 3, Ch 15, 2.6 Configuration management*.

2.12.5 The procedure is to identify the requirements to be validated, the means by which they are be validated and the points in the project at which validation is to be carried out, including:

(a) Factory acceptance testing.
(b) Integration testing.
(c) Commissioning.
(d) Sea trials.
(e) Survey.

■ *Section 3* Software

3.1 General, scope and objectives

3.1.1 Where software is used as the implementation technology for the ISIS then the additional requirements in 3.1.2 to 3.1.9 are to be applied. Where a proposed activity is not undertaken, justification is to be documented and submitted.

3.1.2 A plan for the production of software is to be produced and is to include, but not limit to, the elements listed below.

(a) A full list of software components being developed and, for each, what is required to be produced including code artefacts, tools, specifications, design models, and documentation.
(b) The identification of the deliverables, including those for the purposes of late project phase activities such as boat/platform integration, boat trials, operations and maintenance.
(c) Details of any work that is being subcontracted and how the subcontract will be managed, including specifically ensuring that the Software Development Plan for the software lifecycle will be adhered to.
(d) An identification of the principal project risks arising from the development work.
(e) A definition of the software lifecycle is to be deployed.

(f) The processes, methods, techniques and tools to be used for each phase of the software lifecycle, including:

- pedigree of chosen language, tools and design methods;
- the identification of specific software architecture and software design features appropriate to the reliance being placed on the software; and
- verification performed at each stage of the lifecycle including measures to show that all the requirements, have been correctly translated or implemented by the lifecycle phase activities.

(g) Identify the key personnel in the software development team and in any subcontractors, and their responsibilities. The competency of software development team, especially experience of using the processes, methods, techniques and tools to be used.

(h) Analysis of the software architecture and the software design to confirm that the specific design features which are implemented by functions to satisfy the requirements will work as intended in all modes of operation and failure conditions.

(i) Details of the code implementation and coding standards to be applied to ensure that the software code will be reliable and maintainable.

(j) Validation activities to demonstrate that the functions of the software specifically implemented to satisfy the requirements will operate as intended in all feasible operating scenarios, including:

- testing to show that hazard mitigations work as intended;
- testing and demonstration of safe and acceptable behaviour even in unexpected states, modes and failure conditions; and
- testing that functions implemented to satisfy the requirements work in all credible operating scenarios.

3.1.3 Additional requirements for verification and validation of software components in software-based control systems that handles safety and critical operational functions are listed in 3.1.4 to 3.1.9.

3.1.4 Evidence of satisfying the requirements of ISO/IEC 21119: *Software and Systems Engineering – Software Testing*, or ISO/IEC 61508-3 *Functional safety of electrical/electronic/programmable*, is to meet requirements 3.1.5 to 3.1.9 in this sub-Section.

3.1.5 Evidence is to be submitted that software test scenarios and software test results cover all of the independent paths. Evidence is to be submitted that test results and software static tests on control flow, data flow and design review are to be used to analyse the quality of software code.

3.1.6 For the purpose of black-box testing, evidence is to be submitted that test results, methods, techniques and tools that are acceptable to LR are applied before and after integrations.

3.1.7 Evidence is to be submitted that test results and software tests listed below are to be applied for software verification:

(a) Dynamic analysis and testing for:

Boundary values, structural test coverage (entry points) 100 per cent and structural test coverage (statements) 100 per cent.

(b) Static analysis and testing for:

Control flow, data flow and design review.

(c) Functional and black box testing on:

Equivalence classes and input partition testing including boundary value analysis.

(d) Performance testing for:

Response timings and memory constraints, performance requirements.

(e) Data recording and analysis.

(f) Regression testing.

3.1.8 Evidence is to be submitted that test results and software tests listed below are to be applied for software validation:

- Functional and black box testing.

3.1.9 Evidence that coding reviews have been undertaken is to be submitted.

Wind Turbine Installation and Maintenance Vessels and Liftboats

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines and cover the unit types indicated in 1.2.

1.1.2 The requirements of this Chapter also apply to liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation, *see* 1.2.

1.1.3 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.4 Surface type units and surface type self-elevating units are to comply with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), but aspects which relate to the specialised offshore function of the unit will also be considered on the basis of these Rules.

1.1.5 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the unit is operating.

1.2 General definitions

1.2.1 A **column-stabilised unit** is a unit with a working platform supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed.

1.2.2 A **liftboat** is a unit with a buoyant hull (generally either triangular or pontoon shaped) with moveable legs capable of raising the hull above the surface of the sea and designed to operate as a sea bed-stabilised unit in an elevated mode. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.3 A **self-elevating (or jack-up) unit** is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a buoyant hull (generally either triangular or pontoon shaped) with movable legs capable of raising its hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. These unit types are generally not fitted with a propulsion system.

1.2.4 A **surface type floating unit** is a unit with a ship or barge type displacement hull of single or multiple hull construction intended for operation in the floating condition.

1.2.5 A **surface type self-elevating (or jack-up) unit** is a floating unit, which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a ship type displacement hull of single or multiple hull construction fitted with moveable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.6 Summary information for Liftboats engaged in support services to offshore wind turbine installation or other types of offshore installation can be found in LR's Guidance Note *Mobile Offshore Units – Liftboats*.

1.3 Guidance note

1.3.1 Summary information for unit types engaged in installation and/or maintenance activities relating to offshore wind turbines can be found in LR's Guidance Note Mobile Offshore Units – *Wind Turbine Installation Vessels*.

1.3.2 National Administration requirements.

1.3.3 The Guidance Notes referred to in 1.3.1 and 1.3.2 provide summary information on the following topics:

- Classification Rules, Regulations and procedures.
- National Administration requirements.
- Documentation.
- Applicable LR Rule requirements for unit types identified in 1.2.

1.3.4 For the unit types identified in 1.2.1, 1.2.3, 1.2.4 and 1.2.5, Appendices A2, A3, A4 and A5 of the Guidance Note referred to in 1.3.1 include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.3.5 For the unit type identified in 1.2.2, the Guidance Note referred to in 1.3.2 includes summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.4 Class notations

1.4.1 The Regulations for classification and the assignment of class notations are given in *List of abbreviations*, to which reference should be made.

1.4.2 In general, units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:

- **MainWIND**

1.4.3 In general, liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:

- **Liftboat**

1.4.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Classification Committee.

1.4.5 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment* (LAME), *see also Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.4.6 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation '*LA*' will be assigned, *see Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.4.7 Other special features class notations associated with lifting appliances may be assigned, *see Pt 3, Ch 11 Lifting Appliances and Support Arrangements*.

1.4.8 Where the lifting appliance is not assigned a special feature class notation, the crane is to be certified by a recognised competent body, *see Ch 1, 1.2 Certification*.

1.5 Scope

1.5.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Hull scantlings
- Strength of structure for accommodation.
- Supports for containerised modules.
- Structure in way of cranes.
- Structure below any other major mission equipment, laydown areas, etc.
- Positional mooring.

- Main and auxiliary machinery.
- Control and electrical engineering.
- Safety systems, hazardous areas and fire.
- Corrosion control.

1.6 Installation layout and safety

1.6.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.6.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see Pt 1, Ch 2, 1 Conditions for classification*and *Pt 7, Ch 3 Fire Safety*.

1.6.3 Additional requirements for hazardous areas, safety and communication systems are given in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE* and are to be applied to the relevant unit type. For surface type self-elevating units, the requirements for surface type units are to be complied with as applicable.

1.7 Survey

1.7.1 For all unit types, the requirements for periodical surveys are defined in*Pt 1, Ch 2, 3 Surveys — General*and*Pt 3, Ch 3 Production and Storage Units*.

1.7.2 In general, where a classed or certified lifting appliance is fitted to a classed unit, the survey requirements of the lifting appliance are to be in accordance with CLAME

1.8 Plans and data submission

1.8.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter.

1.8.2 For units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, *see also* Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*, for additional information on the plans and data to be submitted.

1.8.3 For liftboats engaged in support services to offshore wind turbine installation, *see also* LR's Guidance Note *Mobile Offshore Units – Liftboats*, for additional information on the plans and data to be submitted.

■ *Section 2* **Structure**

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels* and also LR's Guidance Note Mobile *Offshore Units – Liftboats*, the following additional plans and information are to be submitted as applicable:

- General arrangement plans.
- Structural plans of the accommodation including deck houses and modules.
- Design calculations for containerised modules (if applicable).
- Structural arrangements in way of crane supports and boom rests (if applicable).
- Structural arrangements in way of permanently attached, purpose built cargo stacking and securing arrangements.
- Structural arrangements under the weather deck which support heavy items of deck cargo such as nacelles, towers, blades, foundations and temporary transportation frames.
- Structural arrangements and supports under any other major mission or topsides equipment.
- Positional mooring equipment and supporting structures (if applicable).

2.2 General

2.2.1 The hull strength is to take into account the applied weights and forces due to the accommodation, deck cargo, cranes and, if applicable, mooring forces and the local structure is to be suitably reinforced. Appendices A2, A3, A4 and A5 of the

Guidance Note referred to in *Pt 3, Ch 16, 1.3 Guidance note* include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types for hull strength requirements.

2.2.2 For the unit types identified in *Pt 3, Ch 16, 1.2 General definitions*, 1.2.3, 1.2.4 and 1.2.5, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in Appendices A2, A3, A4 and A5 of the Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*.

2.2.3 For the unit type identified in *Pt 3, Ch 16, 1.2 General definitions*, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in the Guidance Note *Mobile Offshore Units – Liftboats*.

2.2.4 The design loadings for all purpose built cargo stacking arrangements, support frames and trusses are to be defined by the designers/Builders and calculations are to be submitted in accordance with an internationally recognised Code or Standard as defined in Appendix A. The supporting structure and attachments below the purpose built cargo stacking arrangements, support frames and trusses are to be designed for all operating conditions and for the emergency condition as defined in *Pt 3, Ch 8, 1.4 Plant design characteristics*. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.5 The supporting structure and attachments below any other mission equipment items are to be designed for all operating conditions and for the emergency condition as defined in *Pt 3, Ch 8, 1.4 Plant design characteristics*. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.6 When the unit is intended to operate in an area which could result in the build-up of ice on the crane, leg and any other structure, the effects of ice loading are to be included in the calculations. *See Pt 4, Ch 3, 4 Structural design loads*.

2.2.7 For column-stabilised and self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See Pt 4, Ch 6, 2 Design heads*.

2.2.8 For surface type and surface type self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See Pt 3, Ch 3, 5 Design loading* of the Rules for Ships.

2.2.9 In general, all seatings, platform decks, girders and pillars supporting mission equipment and deck cargo are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads.

2.2.10 Attention should be paid to the capability of support structures to withstand buckling. For column-stabilised and self-elevating units, *see Pt 4, Ch 5, 4 Buckling strength of primary members*. Surface type and surface type self-elevating units are to comply with *Pt 3, Ch 4, 7 Hull buckling strength*of the Rules for Ships, but aspects which relate to the specialised offshore function of the unit will be considered on the basis of *Pt 4, Ch 5, 4 Buckling strength of primary members*.

2.2.11 Crane pedestals are classification items and are to comply with the requirements of Chapter 11.

2.2.12 For liftboats, a fatigue life assessment of all relevant structural elements in accordance with *Pt 4, Ch 5, 5 Fatigue design* is required. Structural elements to be assessed include lattice legs and connections to mats and footings and leg support structure. The fatigue loading spectrum may be based on the transit environmental criteria.

2.2.13 The minimum fatigue life of a liftboat is to be specified by the Owners, but is generally not to be less than 20 years, unless agreed otherwise with LR.

2.2.14 For liftboats, when considering the overturning moment, in no case is the variable load to be taken greater than 10 per cent of the maximum variable load. The percentage of variable load used when considering the overturning moment is to be stated in the Operations Manual.

2.2.15 For liftboats, when calculating the overturning moment, the unit should be considered supported through the centre line of the legs about which the unit is considered rotating. However, for hard foundation bases, the maximum stressed edge of the mat may be taken as an appropriate support position. In this instance, a safety factor of at least 1,2 against overturning is considered acceptable.

2.2.16 For liftboats, the Owner is to specify the minimum design environmental criteria and return periods for which the unit is to be approved. In general, a return period of not less than 1 year should be used for operational conditions and 100 years for survival conditions.

2.2.17 For liftboats, restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must be specified. The unit's actual minimum design environmental criteria and return periods used in the design of the liftboat are to be stated in the Operations Manual.

2.2.18 The thickness of marine growth to be taken into account during the design of submerged members on lift boats is not to be less than 50 mm. The actual thickness of marine growth used in the design of the liftboat is to be stated in the Operations Manual and the design limit is not to be exceeded in service.

2.2.19 For liftboats, the minimum design deck loads are to be specified by the Owner and are not to be less than the minimum design deck loads required by Pt 4, Ch 6,2.

2.2.20 For liftboats, the foundation fixity need not be considered for the in-place strength analysis.

2.3 Deckhouses and modules

2.3.1 For column-stabilised and self-elevating units, the scantlings of structural deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.2 For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with *Pt 3, Ch 8, 2 Scantlings of erections other than forecastles* of the Rules for Ships. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.3.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by 2.3.1 or 2.3.2, as applicable.

2.3.5 For column-stabilised and self-elevating units, the structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of *Pt 4, Ch 6, 9 Superstructures and deckhouses*, taking into account the unit's motions and marine environmental aspects. For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with *Pt 3, Ch 8, 2 Scantlings of erections other than forecastles*of the Rules for Ships.

2.3.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_{H} in any direction as follows:

$F_{\mathrm{H}} = W \sin\theta$ N (tonne-f)

where

θ = 25° for semi-submersible and surface type units

θ = 17° for self-elevating and surface type self-elevating units

W = weight of the modules supported in N (tonne-f).

2.3.7 In the emergency static condition, defined in 2.3.6, the permissible stress levels are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

2.4 Permissible stresses

2.4.1 In general, for column-stabilised and self-elevating units the permissible stresses in the structure in operating, transit and survival conditions are to comply with *Pt 4, Ch 5, 2 Permissible stresses*, but the minimum scantlings of the local structure are to comply with *Pt 4, Ch 6 Local Strength*.

2.4.2 In general, for surface type and surface type self-elevating units the primary hull strength and the minimum scantling requirements for the local structure can be considered under *Pt 3, Ch 4 Longitudinal Strength*and *Pt 4, Ch 1 General Cargo Ships*of the Rules for Ships. However, aspects which relate to the specialised offshore function of the unit will be considered under the basis of*Pt 4, Ch 5, 2 Permissible stresses*.

2.4.3 Permissible stresses for lattice type structures may be determined from an acceptable code, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.5 Watertight and weathertight integrity

2.5.1 For column-stabilised and self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

2.5.2 For surface type and surface type self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with *Pt 3, Ch 11 Closing Arrangements for Shell, Deck and Bulkheads*and *Pt 3, Ch 12 Ventilators, Air Pipes and Discharges* of the Rules for Ships.

2.5.3 The integrity of the weather deck is to be maintained. Where mission equipment penetrates the weather deck and is intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, its structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deck-houses fully complying with the Rules. Full details are to be submitted for approval.

2.5.4 Where items of mission equipment penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.6 Materials

2.6.1 For column-stabilised and self-elevating units, the general requirements for materials are to be in accordance with *Pt 3, Ch 1, 4 Materials* and *Pt 4, Ch 2 Materials*.

2.6.2 For surface type and surface type self-elevating units, the general requirements for materials are to be in accordance with *Pt 3, Ch 2 Materials* and *Pt 4, Ch 1, 2 Materials and protection* of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered under the basis of *Pt 3, Ch 1, 4 Materials*and *Pt 4, Ch 2 Materials*.

■ *Section 3*
Positional mooring systems

3.1 Application

3.1.1 The requirements of this Section apply to units which are intended to perform their primary designed service function only while they are moored with a catenary type positional mooring system including thruster-assisted systems.

3.1.2 The mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

3.1.3 The mooring system is to comply with the requirements of *Pt 3, Ch 10 Positional Mooring Systems*.

3.1.4 For column-stabilised and self-elevating units, dynamic positioning systems are to comply with the requirements of Chapter 9. For surface type and surface type self-elevating units, dynamic positioning systems are to comply with the requirements of *Pt 7, Ch 4 Dynamic Positioning Systems* of the Rules for Ships.

3.1.5 The support structure in way of fairleads and winches, etc., are to be in accordance with *Pt 4, Ch 6, 1 General requirements*.

■ *Section 4*
Main and auxiliary machinery

4.1 Application

4.1.1 For surface type units, the general requirements for main and auxiliary machinery are to be in accordance with *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery* of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of*Pt 5, Ch 1 General Requirements for Offshore Units* and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with *Pt 5, Ch 2 Reciprocating Internal Combustion Engines* of the Rules for Ships and are to be complied with as applicable.

4.1.2 For surface type self-elevating units, the general requirements for main and auxiliary machinery are to be in accordance with Pt 5, Ch 1 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of *Pt 5, Ch 1 General Requirements for Offshore Units* and*Pt 3, Ch 4, 2 Structure*, and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with *Pt 5, Ch 2 Reciprocating Internal Combustion Engines* of the Rules for Ships and are to be complied with as applicable.

4.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with *Pt 5 MAIN AND AUXILIARY MACHINERY* and are to be complied with as applicable.

4.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

4.2 Angle of inclination

4.2.1 For surface type units, the angles of inclination are to be in accordance with *Pt 5, Ch 1, 3.7 Inclination of ship* of the Rules for Ships.

4.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with *Pt 5, Ch 1, 3.7 Inclination of ship* of the Rules for Ships.

4.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with *Pt 5, Ch 1, 3.7 Inclination of ship*.

4.3 Bilge systems and cross flooding arrangements

4.3.1 For all unit types with accommodation for more than 12 persons who are not crew members, the requirements of *Pt 3, Ch 4, 3 Bilge systems and cross-flooding arrangements for accommodation units*are to be complied with as applicable.

4.4 Jacking gear machinery

4.4.1 For all types of self-elevating units, the number of jacking cycles expected to be seen during the unit's intended design life will need to be specially considered in the design of the jacking gear machinery. Relevant calculations will be required to be submitted, taking into account the expected number of jacking cycles during the unit's intended design life.

■ *Section 5* Control and electrical engineering

5.1 Application

5.1.1 For surface type units, the control and electrical engineering requirements are to be in accordance with*Pt 6 Control, Electrical, Refrigeration and Fire*of the Rules for Ships, and are to be complied with as applicable.

5.1.2 For surface type self-elevating units, the control and electrical engineering requirements are to be in accordance with*Pt 6 Control, Electrical, Refrigeration and Fire* of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of*Pt 6, Ch 1 Control Engineering Systems* and*Pt 6, Ch 2 Electrical Engineering*and are to be complied with as applicable.

5.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with *Pt 6 CONTROL AND ELECTRICAL ENGINEERING*and are to be complied with as applicable.

5.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

5.2 Angle of inclination

5.2.1 For surface type units, the angles of inclination are to be in accordance with *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*of the Rules for Ships.

5.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*of the Rules for Ships.

5.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*.

5.3 Emergency source of electrical power

5.3.1 For all unit types with accommodation for more than 50 persons who are not crew members, the requirements of *Pt 3, Ch 4, 4.2 Emergency source of electrical power*are to be complied with as applicable.

■ Section 6
Safety systems, hazardous areas and fire

6.1 Application

6.1.1 For all unit types, the safety systems, hazardous areas and fire safety requirements are to be in accordance with the requirements of*Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*, and are to be complied with as applicable.

6.1.2 The requirements of *Pt 3, Ch 11, 1.1 General*, are not applicable to surface type units and surface type self-elevating units. For these unit types, the requirements of *Pt 3, Ch 11, 9 Watertight doors in bulkheads below the freeboard deck* of the Rules for Ships are to be complied with as applicable.

6.1.3 For surface type self-elevating units, the remaining requirements in *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE* for surface type units are to be complied with as applicable.

6.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

■ Section 7
Corrosion control

7.1 Application

7.1.1 For all unit types, the corrosion control requirements are to be in accordance with Part 8 and are to be complied with as applicable.

7.1.2 The minimum corrosion protection requirements for external structural steel work for surface type self-elevating units are to comply with *Pt 8, Ch 1 General Requirements for Corrosion Control*. The unit's main hull and all structure above the splash zone are to comply with the requirements for a surface type unit. The legs, footings and mats for these units are to comply with the requirements for a self-elevating unit.

■ *Section 1* Codes and Standards

1.1 Abbreviations

1.1.1 The following abbreviations are used in this Appendix:

AISC American Institute of Steel Construction.
ANSI American National Standards Institute.
API American Petroleum Institute.
ASME American Society of Mechanical Engineers.
BS British Standard.
CAA. United Kingdom Civil Aviation Authority.
CAP. United Kingdom Civil Aviation Authority Procedure.
CSA Canadian Standards Association.
DIN Deutsches Institut für Normung.
EEMUA Engineering Equipment & Materials Users Association
EN. European Standard
IEC. International Electrotechnical Commission
IMCA. International Marine Contractors Association
FEM Fédération Européenne de la Manutention.
IP International Petroleum.
ISO International Standards Organisation.
NACE National Association of Corrosion Engineers.
NS Norwegian Standard.
NFPA National Fire Protection Association.
OGP International Association of Oil and Gas Producers
TBK Norwegian Pressure Vessel Committee.
UKOOA United Kingdom Offshore Operators Association.

1.2 Recognised Codes and Standards

1.2.1 The following Codes and Standards are recognised by LR in connection with the design, construction and installation of equipment and components which form part of the structural and mechanical systems installed on offshore units as appropriate.

1.2.2 The following National and International Codes and Standards listed are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

1.2.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR.

1.2.4 **Blow out prevention:**

API Spec. 16A *Specification for Drill through Equipment.*
API Std 53 *Blowout Prevention Equipment Systems for Drilling Operations.*
API RP 16E *Design of Control Systems for Drilling Well Control Equipment.*

1.2.5 **Lifting appliances:**

API Spec 2C *Specification for Offshore Pedestal Mounted Cranes.*

ASME B30.20 *Below the Hook Lifting Devices.*

API Spec 8C *Drilling and Production Hoisting Equipment.*

EN 13586+A1 *Cranes - Access*

EN 13852-1 *Cranes - Offshore cranes - Part 1: General purpose offshore cranes*

EN 13852-2 *Cranes - Offshore cranes - Part 2: Floating cranes*

FEM 1.001 *Section-1: Heavy lifting appliances – Rules for the design of Hoisting Appliance Methods of Strength Calculation.*

ISO 2374 *Lifting Appliances – Range of Maximum Capacities for Basic Models.*

ISO 4309 *Cranes - Wire Ropes - Care and Maintenance, Inspection and Discard*

ISO 8383 *Lifts on ships - Specific requirements*

ISO 8566 *Cranes - Cabins and control stations*

ISO 10245 *(all parts) Cranes – Limiting and indicating devices.*

ISO 13534 *Petroleum and natural gas industries – Drilling and production equipment – Inspection, maintenance, repair and remanufacture of hoisting equipment.*

ISO 13535 *Petroleum and natural gas industries – Drilling and production equipment – Hoisting equipment.*

LR's *Code for Lifting Appliances in a Marine Environment*.

1.2.6 **Derrick:**

API 4E *Drilling and Well Servicing Structures.*

1.2.7 **Drilling equipment:**

API Spec. 7 *Specification for Rotary Drilling Equipment.*

API RP 7G *Drill Stem Design and Operating Limits.*

API Spec. 8A and 8C *Drilling and Production Hoisting Equipment.*

API RP 8B *Hoisting Tool Inspection and Maintenance Procedures.*

API Spec. 9A *Wire Rope.*

API RP 9B *Application, Care and Use of Wire Rope for Oil Field Service.*

ISO 10405 *Petroleum and natural gas industries – Care and use of casing and tubing.*

ISO 10407 *Petroleum and natural gas industries – Drilling and production equipment – Drill stem design and operating limits.*

ISO 10426 *Petroleum and natural gas industries – Cements and materials for well cementing.*

ISO 11960 *Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*

ISO 11961 *Petroleum and natural gas industries – Steel pipes for use as drill pipe – Specification.*

ISO 13500 *Hydraulic fluid power – Determination of particulate contamination by automatic counting using the light extinction principle.*

ISO 13533 *Petroleum and natural gas industries – Drilling and production equipment – Drill-through equipment.*

ISO 14693 *Petroleum and natural gas industries – Drilling and well-servicing equipment.*

ISO 13678 *Petroleum and natural gas industries – Evaluation and testing of thread compounds for use with casing, tubing and line pipe.*

ISO 13680 *Petroleum and natural gas industries – Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock – Technical delivery conditions.*

FEM 1001 3rd Edition: *Rules for the Design of Hoisting Appliances, Section 1, Booklets 3 to 8.*

1.2.8 **Wellhead equipment:**

API Spec. 6A & ISO 10423 *Wellhead and Christmas Tree: Equipment.*

API Spec. 14D *Wellhead Surface Safety Valves and Underwater Safety Valves for Offshore Service.*

API RP 14B *Design, Installation and Operation of Subsurface Safety Valve Systems.*

API RP 17D *Specification for Subsea Wellhead and Christmas Tree Equipment.*

1.2.9 **Piping Systems and Materials:**

ASME B16.47 *Large Diameter Steel Flanges: NPS 26 Through NPS 60.*

ASME B16.5 *Pipe Flanges and Flanged Fittings.*

ANSI/ASME B31.3 *Process piping.*

BS 3351 *Specification for Piping Systems for Petroleum Refineries and Petrochemical Plants.*

ISO 13703 *Petroleum and natural gas industries – Design and installation of piping systems on offshore production platforms.*

API RP 14E *Design and Installation of Offshore Production Platform Piping Systems.*

API RP 17B *Flexible Pipe.*

API RP 520 *Design and Installation of Pressure Relieving Systems in Refineries.*

API RP 521 *Guide for Pressure Relieving and Depressurising Systems.*

API Spec 6D *Pipeline Valves (Gate, Plug, Ball and Check Valves)*.

API Spec 6FA *Fire Test for Valves*.

API STD 6AV2 *Installation, Maintenance, and Repair of Surface Safety Valves and Underwater Safety Valves Offshore*

API RP 16C *Specification for Choke and Kill Systems.*

ASME B40.100 *Pressure Gauges and Gauge Attachments.*

ISO 10434 *Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries.*

ISO 13623 *Petroleum and natural gas industries – Pipeline transportation systems.*

ISO 13847 *Petroleum and natural gas industries – Pipeline transportation systems – Welding of pipelines.*

ISO 14313 *Petroleum and natural gas industries – Pipeline transportation systems – Pipeline valves.*

ISO 1461 *Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods*

ISO 14726 *Ships and marine technology – Identification colours for the content of piping systems*

ISO 15649 *Petroleum and natural gas industries – Piping.*

ISO 15761 *Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries.*

ISO 8434-1 *Metallic tube connections for fluid power and general use – Part 1: 24 deg cone connectors*

UKOOA *Specification and Recommended Practice for the Use of GRP Piping Offshore.*

API RP 2RD *Riser Design.*

API RP 16R *Design Rating and Testing of Marine Drilling Riser Couplings.*

API RP 16Q *Design and Operation of Marine Drilling Riser Systems.*

API Bul 2J *Comparison of Marine Drilling Riser Analysis.*

API RP 17B *Recommended Practice for Flexible Pipe.*

API Spec.17J *Specification for Unbonded Flexible Pipe.*

BS PD 8010 *Code of Practice for Pipelines, Part 3, Pipelines Subsea: Design, Construction and Installation.*

ISO 3183 *Petroleum and natural gas industries – Steel pipe for pipeline transportation systems.*

ISO 10414 *Petroleum and natural gas industries – Field testing of drilling fluids.*

ISO 10426 *Petroleum and natural gas industries – Cements and materials for well cementing.*

ISO 10427 *Petroleum and natural gas industries – Equipment for well cementing.*

ISO 11960 *Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*

ISO 15156 *Petroleum and natural gas industries – Materials for use in* H_2S *-containing environments in oil and gas production.*

ISO 15463 *Petroleum and natural gas industries – Field inspection of new casing, tubing and plain-end drill pipe.*

ISO 16070 *Petroleum and natural gas industries – Downhole equipment – Lock mandrels and landing nipples.*

ISO 18165 *Petroleum and natural gas industries – Performance testing of cementing float equipment.*

ISO 15590 *Petroleum and natural gas industries – Induction bends, fittings and flanges for pipeline transportation systems.*

1.2.10 **Pressure vessels/fired units/heat exchangers:**

TBK-1-2 *General Rules for Pressure Vessels.*

PD 5500 *Unfired Fusion Welded Pressure Vessel.*

ASME Section 1 *Power Boilers.*

ASME Section IV *Heating Boilers.*

ASME BPVC Sec I *Boiler And Pressure Vessel Code, Section I, Rules For The Construction Of Power Boilers.*

ASME BPVC Sec IX *Boiler And Pressure Vessel Code, Section Ix, Welding And Brazing Qualifications.*

ASME BPVC Sec V *Boiler And Pressure Vessel Code, Section V, Nondestructive Examination.*

ASME BPVC Sec VIII-1 *Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 1.*

ASME BPVC Sec VIII-2 *Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 2 – Alternative Rules.*

ASME BPVC Sec VIII-3 *Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 3 – Alternative Rules For Construction Of High Pressure Vessels.*

BS 2790 *Shell Boiler of Welded Construction.*

TEMA *Standards of the Tubular Exchangers Manufacturers Association.*

WRC Bull 107 *Welding Research Council – Local Stresses in Spherical and Cylindrical Due to External Loading.*

WRC Bull 297 *Welding Research Council – Local Stresses in Spherical and Cylindrical Shells Due to External Loading on nozzles – Supplement to WRC Bull 107.*

EEMUA *PUB No 143 Recommendations for Tube End Welding: Tubular Heat Transfer Equipment (Part 1 – Ferrous Materials).*

API RP 530 *Calculation of Heater. Tube Thickness in Petroleum Refineries.*

API 660 *Shell and tube heat exchangers for general refinery service.*

API 661 *Air Cooled Heat Exchangers for General Refinery Service.*

API 662 *Plate Heat Exchanger for General Refinery Services.*

BS EN 12952 *Water-Tube Steam Generating Plant.*

ISO 13704 *Petroleum, petrochemical and natural gas industries – Calculation of heatertube thickness in petroleum refineries.*

ISO 13706 *Petroleum, petrochemical and natural gas industries – Air-cooled heat exchangers.*

ISO 15547 *Petroleum, petrochemical and natural gas industries – Plate-type heat exchangers.*

ISO 13705 *Petroleum, petrochemical and natural gas industries – Fired heaters for general refinery service.*

ISO 16812 *Petroleum, petrochemical and natural gas industries – Shell-and-tube heat exchangers.*

ISO 16812 *Petroleum, petrochemical and natural gas industries – Shell-and-tube heat exchangers.*

1.2.11 **Process plant equipment:**

API 610 *Centrifugal Pumps for General Refinery Service.*

API 615 *Sound Control of Mechanical Equipment for Refinery Service.*

API 617 *Centrifugal Compressors for General Refinery Services.*

API RP 14C *Recommended Practices for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms.*

API RP 550 *Recommended Practice: Manual on Installation of Refinery Instruments and Control Systems, Parts 1 to 4.*

API Std 613 *Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services.*

API Std 614 *Lubrication, Shaft-Sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services.*

API Std 618 *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.*

API Std 619 *Rotary Type Positive Displacement Compressors for Petroleum, Chemical, and Gas Industry Services.*

API Std 620 *Design and Construction of large, welded, low-pressure storage tanks.*

API Std 650 *Welded steel tanks for oil storage.*

API Std 670 *Machinery Protection Systems.*

API Std 671 *Special purpose Couplings for Petroleum, Chemical and Gas Industry Services.*

API Std 672 *Packaged, integrally geared, centrifugal air compressors for petroleum, chemical and gas industry services.*

API Std 673 *Centrifugal Fans for Petroleum, Chemical and Gas Industry Service.*

API Std 674 *Positive displacement pumps – Reciprocating.*

API Std 675 *Positive displacement pumps – Controlled volume.*

API Std 676 *Positive displacement pumps – Rotary.*

API Std 681 *Liquid Ring Vacuum Pumps and Compressors for Petroleum, Chemical, and Gas Industry Services.*

API Std 682 *Shaft Sealing Systems for Centrifugal and Rotary Pumps.*

API 616 *Combustion Gas Turbines for General Refinery Service.*

ASME B73.1 *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process.*

ASME B73.2M *Specification for Vertical In-Line Centrifugal Pumps for Chemical Process.*

ISO 2314 *Gas Turbine Acceptance Tests.*

ISO 2858 *End-suction centrifugal pumps (rating 16 bar) – Designation, nominal duty point and dimensions.*

ISO 2954 *Mechanical vibration of rotating and reciprocating machinery – Requirements for instruments for measuring vibration severity.*

ISO 3046 *(all parts) Reciprocating internal combustion engines – Performance.*

ISO 3977 *(all parts) Gas turbines – Procurement. ISO 5199 Technical specs. for centrifugal pumps- Class II.*

ISO 9906 *Roto-dynamic pumps – Hydraulic performance acceptance tests – Grades 1 and 2.*

ISO 10431 *Petroleum and Natural Gas Industries – Pumping Units – Specification.*

ISO 10436 *Petroleum and Natural Gas Industries – General purpose steam turbines for refinery service.*

ISO 10440 *(all parts) Petroleum and Natural Gas Industries – Positive displacement-rotary type compressors.*

ISO 10441 *Petroleum, petrochemical and natural gas industries – Flexible couplings for mechanical power transmission – Special-purpose applications.*

ISO 13707 *Petroleum and natural gas industries – Reciprocating compressors.*

ISO 14691 *Petroleum and natural gas industries – Flexible couplings for mechanical power transmission – General purpose applications.*

ISO 10437 *Petroleum, petrochemical and natural gas industries – Steam turbines – Special-purpose applications.*

ISO 10438 *Petroleum, petrochemical and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*

ISO 10439 *Petroleum, chemical and gas service industries – Centrifugal compressors.*

ISO 13631 *Petroleum and natural gas industries – Packaged reciprocating gas compressors.*

ISO 13691 *Petroleum and natural gas industries – High-speed special-purpose gear units.*

ISO 14310 *Petroleum and natural gas industries – Downhole equipment – Packers and bridge plugs.*

ISO 15136 *Downhole equipment for petroleum and natural gas industries – Progressing cavity pump systems for artificial lift.*

NFPA No. 37 *Stationary Combustion Engines and Gas Turbines.*

EEMUA *PUB No 141 Guide to the use of Noise Procedure Specification.*

1.2.12 **General structural items (skids, support frames and trusses etc.):**

BS 5950 *Structural Use of Steelwork in Building.*

AISC *Manual of Steel Construction – Allowable Stress Design.*

BS 2853 *The Design and Testing of Steel Overhead Runway Beams.*

BS EN 1993 *Eurocode 3: Design of Steel Structures.*

BS 6399-2 *Loads for Buildings, Code of Practice for Wind Loads.*

BS 8118 *Structural Use of Aluminium.*

API BUL 2U *Design of Flat Plate Structures.*

AISC LRFD *Manual of Steel Construction – Load and Resistance Factor Design.*

API RP 2A – WSD *Recommended Practice for Planning, Design and Constructing Fixed Offshore Platforms Working Stress Design.*

BS 8100 *Lattice Towers and Masts.*

API RP 2SK *Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.*

EN 1337-1*Structural bearings – Part 1: General design rules.*

EN 1337-2*Structural bearings – Part 2: Sliding elements.*

EN 1337-3*Structural bearings – Part 3: Elastomeric bearings.*

EN 1337-8*Structural bearings – Part 8: Guide bearings and restrain bearings.*

EN 1337 *Structural bearings – Part 5: European Standard, Construction Standardisation: Pot Bearing.*

EN 1337-9*Structural bearings – Part 9: Protection.*

EN 1337-10 *Structural bearings – Part 10: Inspection and maintenance.*

EN 1337-11 *Structural bearings – Part 11: Transport, storage and installation.*

Euro-code 3 *Design of steel structures – Part 2: Steel Bridge.*

BS 5400*Steel, Concrete and Composite Bridges – Part 9: Bridge Bearing.*

1.2.13 **Hazardous area classification:**

API RP 500 *Classification of Locations for Electrical Installations at Petroleum Facilities.*

API RP 505 *Classification of Locations for Electrical Installations at Petroleum Facilities, Classed as Class I, Zones 0, 1 & 2.*

EN 13463 *series Non-electrical equipment for use in potentially explosive atmospheres*

EN 14986 *Design of fans working in potentially explosive atmospheres*

IEC 60079 *series Explosive atmospheres*

IP Code, Part 3 *Refining Safety Code.*

IP Code, Part 8 *Drilling and Production Safety Code for Offshore Operations.*

IP Code, Part 15 *Area Classification Code for Petroleum Installations.*

ISO 15138 *Petroleum and natural gas industries – Offshore production installations – Heating, ventilation and air-conditioning.*

Note production units only

ISO 17776 *Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment.*

1.2.14 **Fire and safety standards:**

ISO 13702 *Petroleum and natural gas industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines.*

ISO 15370 *Ships and marine technology – Low location lighting (LLL) on passenger ships – Arrangement*

ISO 15544 *Petroleum and natural gas industries – Offshore production installations – Requirements and guidelines for emergency response.*

ISO 17631 *Ships and marine technology – Shipboard plans for fire protection, life-saving appliances and means of escape*

ISO 24409-1 *Ships and marine technology – design, location and use of shipboard safety signs, safety notices and safety markings - Part 1: Design principles*

NFPA No. 1 *Fire Prevention Code.*

NFPA No. 10 *Portable Extinguishers.*

NFPA No. 11 *Low-Expansion Foam.*

NFPA No. 11A *Medium- and High-Expansion Foam Systems.*

NFPA No. 11C *Mobile Foam Apparatus.*

NFPA No. 12 *Carbon Dioxide Systems.*

NFPA No. 12A *Halon 1301 Systems.*

NFPA No. 13 *Sprinkler Systems.*

NFPA No. 15 *Water Spray Fixed Systems.*

NFPA No. 14 *Standpipe, Hose Systems.*

NFPA No. 16 *Deluge Foam-Water Systems.*

NFPA No. 16A *Closed Head Foam-Water Sprinkler Systems.*

NFPA No. 17 *Dry Chem. Ext. Systems.*

NFPA No. 17A *Wet Chem. Ext. Systems.*

NFPA No. 20 *Centrifugal Fire Pumps.*

NFPA No. 25 *Water-based Fire Protection Systems.*

NFPA No. 68 *Venting of Deflagrations.*

NFPA No. 69 *Explosion Prevention Systems.*

NFPA No. 80 *Fire Doors and Fire Windows.*

NFPA No. 170 *Fire Safety Symbols.*

NFPA No. 704 *Fire Hazards of Materials.*

NFPA No. 750 *Standard for Installation of Water Mist Fire Suppression System.*

NFPA No. 2001 *Clean Agent Ext. Systems.*

HSE OTI 95-634 *Jet Fire Resistance Test of Passive Fire Materials.*

1.2.15 **Bearings:**

ANSI/AFBMA *Std 11 Load Ratings and Fatigue Life for Roller Bearings.*

ASME 77-DE-39 *Design Criteria to Prevent Core Crushing Failure in Large Diameter Case Hardened Ball and Roller Bearings.*

BS 5512:1/ISO 281*Dynamic Load Ratings and Rating Life of Rolling Bearings.*

BS 5645:/ISO 76*Static Load Ratings for Rolling Bearings.*

ISO 281 *Roller Bearing-Dynamic Load Ratings and Rating Life.*

ISO 10438 *(all parts) Petroleum and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*

1.2.16 **Wind gust spectra formulations:**

API RP 2A *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms.*

Deaves D.M & Harris R.I 1978 *A mathematical model of the structure of strong winds, CIRIA Report No. 76.*

Slettringen (Norwegian Petroleum Directorate)

1.2.17 **Wave contour development:**

Environmental Parameters for Extreme Response: Inverse Form with Omission Factors, Winterstein et al, ISBN No. 9054103571.

1.2.18 **Codes for concrete structures:**

BS 8110 *Structural Use of Concrete, Parts 1, 2 and 3.*

NS 3473 *Concrete Structures – Design Rules.*

CSA S471 *General Requirements, Design Criteria, the Environment and Loads.*

CSA S474 *Concrete Structures, Offshore Structures.*

ISO 19903 *Fixed Concrete Structures.*

Other publications:

- Norwegian Petroleum Directorate, Guidelines relating to concrete structures to regulations relating to load bearing structures in the petroleum activities.

1.2.19 **Helidecks:**

CAP 437 *Standards for Offshore Helicopter Landing Areas*

CAA Paper 2008/03 *Helideck Design Considerations – Environmental Effects*

1.2.20 **Safety of Machinery:**

ISO 12100 *Safety of machinery - General principles for design - Risk assessment and risk reduction*

ISO 13850 *Safety of machinery - Emergency stop - Principles for design*

ISO 14122 *series - Safety of Machinery - Permanent Means of Access to Machinery*

1.2.21 **Dynamic Positioning Systems:**

IMCA M 103 *Guidelines for the design and operation of dynamically positioned vessels*

1.2.22 **Compressed Air Systems:**

ISO 1217 *Displacement compressors - Acceptance Tests*

ISO 8573 -1 *Compressed Air - Part 1: Contaminants and purity classes*

1.2.23 **Combustion Engines and Fuels:**

ISO 8217 *Petroleum products - Fuels (class F) - Specifications of marine fuels*

ISO 22241 series *- Diesel engines - NOx reduction agent AUS 32*

1.2.24 **Ventilation:**

ISO 7547 *Ships and marine technology – Air conditioning and ventilation of accommodation spaces - Design conditions and basis of calculation*

ISO 8861 *Ships and marine technology – Engine room ventilation in diesel engine ships – Design conditions and basis of calculation*

ISO 9943 *Shipbuilding – Ventilation and air-treatment of galleys and pantries with cooking appliances*

ISO 15138 *Petroleum and natural gas industries - offshore production installations - heating, ventilation and air-conditioning*

Note production units only

1.2.25 **Subsea:**

ISO 14723 *Petroleum and natural gas industries – Pipeline transportation systems – Subsea pipeline valves.*

ISO 13628-1 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 1: General requirements and recommendations.*

ISO 13628-2 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 2: Unbonded flexible pipe systems for subsea and marine applications.*

ISO 13628-3 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 3: Through flowline (TFL) systems.*

ISO 13628-4 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 4: Subsea wellhead and tree equipment.*

ISO 13628-5 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5: Subsea umbilicals.*

ISO 13628-6 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 6: Subsea production control systems.*

ISO 13628-9 *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 9: Remotely Operated Tool (ROT) intervention systems.*

1.2.26 **Geotechnical**

- Geotechnical & Geophysical Investigations for Offshore and Nearshore Developments, International Society for Soil Mechanics and Geotechnical Engineering, 2005
- ISO 19901-2, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria*
- ISO 19901-4, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*
- ISO 19901-7, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Station keeping systems for floating offshore structures and mobile offshore units*
- ISO 19901-8, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 8:Marine Soil Investigations*
- IMCA S 012, *Guidelines on installation and maintenance of GNSS-based positioning systems, August 2009*
- IMCA S 015 *Guidelines for GNSS based positioning systems in the oil and gas industry, July 2011*
- IMCA S 017, *Guidance on vessel USBL systems for use in offshore survey and positioning operations, April 2011*

1.2.27 **Cryogenic process equipment:**

API 526 *Flanged steel pressure relief valves*

API 527 *Seat tightness of pressure relief valves*

BS 6364 *Specification for valves for cryogenic service - Appendix A applicable*

EEMUA 147 *Recommendations for Liquefied Gas Storage Tanks*

EN 1160 *Installations and equipment for liquefied natural gas. General characteristics of liquefied natural gas*

EN 12434 *Cryogenic vessels – Cryogenic flexible hoses*

EN 1252-1 *Cryogenic vessels – Materials – Part 1: Toughness requirements for temperatures below -80°C*

EN 1252-2 *Cryogenic vessels – Materials – Part 2: Toughness requirements for temperatures between -80°C and -20°C*

EN 13371 *Cryogenic vessels – Couplings for cryogenic service*

EN 14197-1 *Cryogenic vessels – Static non-vacuum insulated vessels – Part 1: Fundamental requirements*

EN 14197-2 *Cryogenic vessels – Static non-vacuum insulated vessels – Part 2: Design, fabrication, inspection and testing*

EN 14197-3 *Cryogenic vessels – Static non-vacuum insulated vessels – Part 3: Operational Requirements*

EN 1473 *Installation and equipment for liquefied natural gas. Design of onshore installations*

EN 1474-1 *Installation and equipment for liquefied natural gas. Design and testing of marine transfer systems. Design and testing of transfer arms*

EN 1474-2 *Installation and equipment for liquefied natural gas. Design and testing of marine transfer systems. Design and testing of transfer hoses*

EN 1474-3 *Installation and equipment for liquefied natural gas. Design and testing of marine transfer systems. Offshore transfer systems*

ISO 10497 *Fire endurance testing for ESD valves*

ISO 10790 *Guidance to the selection, installation and use of Coriolis flow meters*

ISO 10976 *Measurement of cargoes on board LNG carriers*

ISO 18132-1 *Tank gauges for LNG on board marine carriers and floating storage*

ISO 18132-2 *General requirements for automatic level gauges – refrigerated*

ISO 21009-1 *Static vacuum insulated vessels*

ISO 21010 *Gas/materials compatibility for cryogenic vessels*

ISO 21011 *Valves for cryogenic service*

ISO 21013-1 *Pressure-relief accessories for cryogenic service – reclosable*

ISO 21013-2 *Pressure-relief accessories for cryogenic service - non-reclosable*

ISO 21013-3 *Pressure-relief accessories for cryogenic service – sizing*

ISO 21013-4 *Pilot operated pressure relief devices*

ISO 21014 *Cryogenic insulation performance*

ISO 23251 *Pressure-relieving and depressuring systems*

ISO 24490 *Pumps for cryogenic service*

ISO 28460 *LNG Ship to shore interface*

ISO 28921-1 *Isolating valves for low-temperature applications*

ISO 8143 *Thermal insulation products for industrial installations*

ISO 8943 *Sampling of liquefied natural gas -- Continuous and intermittent*

ISO/TS 17177 *Guidelines for the marine interfaces of hybrid LNG terminals*

ISO/TS 18683 *Guidelines for systems and installations for supply of LNG as fuel*

NFPA 59A *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*

1.2.28 **Materials for $H2_S$ Service:**

ISO 15156-1 *Petroleum and natural gas industries – Materials for use in H_2S- containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials.*

ISO 15156-2 *Petroleum and natural gas industries – Materials for use in H_2S - containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.*

ISO 15156-3 *Petroleum and natural gas industries – Materials for use in H_2S - containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys.*

NACE MR0175/ISO 15156 *Petroleum and Natural gas industries materials for use in H_2S containing environment in oil and gas production*

1.2.29 **Control and electrical systems:**

Recognised codes and standards for control engineering systems are found in *Pt 6, Ch 3 Appendix A Control Engineering Systems*.

1.2.30 **Coating application:**

ISO 1461 *Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods*

ISO 8501-1 *Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness – Part1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 12944 *series Paints and varnishes – Corrosion protection of steel structures by protective paint systems*

ISO 20340 *Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures*

1.2.31 **Reliability Centred Maintenance:**

NACE MR0175/ISO 15156 *Petroleum and Natural gas industries materials for use in H_2S H2S-containing environment in oil and gas production.*

ISO 19901-4 (2003) *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations.*

ISO 15156-1 *Petroleum and natural gas industries – Materials for use in H_2S -containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials.*

ISO 15156-2 *Petroleum and natural gas industries – Materials for use in H_2S -containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.*

ISO 15156-3 *Petroleum and natural gas industries – Materials for use in H_2S -containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys.*

ISO 14224 *Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment.*

■ *Section 2*
Equipment categories

2.1 Drilling equipment

2.1.1 A list of usual drilling equipment with its categories is given in *Table 17.2.1 Usual drilling equipment with its categories* .

Table 17.2.1 Usual drilling equipment with its categories

Systems and types of equipment	Category	Description of equipment
1. Well protection valves with control systems		
1.1 Blow out prevention		
1.1.1 Equipment	1A	Hydraulic connector for wellhead
	1A	Ram preventers
	1A	Annular preventers
	1B	Accumulators for sub-sea stack
	1B	Sub-sea fail-safe valves in choke and kill lines
	1A	Clamp
	1B	Test stump
1.1.2 Control equipment	1A	Electrical/electronic control systems
	1A	Deadman systems
	1A	Autoshear system
	1A	Emergency disconnect system
	1B	Accumulators in control system
	1B	Welded pipes and manifolds
	II	Unwelded hydraulic piping
	II	Flexible control hoses
	II	Hydraulic hose reel
	II	Hydraulic power unit including pumps and manifold
	II	Control pads
	1B	Acoustic transportable emergency power package
	II	Control panels
1.2 Choke and kill equipment	1A	Choke manifold
	1B	All piping to and from choke manifold
	1B	Piping for choke, kill and booster lines
	1B	Flexible hoses for choke, kill and booster lines
	1B	Valves in choke, kill and booster lines
	1B	Unions and swivel joints
	1B	Emergency circulation pump – pressure side
1.3 Diverter unit	1A	Diverter house with annular valve

	1B	Diverter piping
	1B	Valves in diverter piping
	II	Control panel
	II	Hydraulic power unit including pumps and manifold
2. Marine riser with control systems	1A	Hydraulic connector
	1A	Ball joint and flexible joint
	1A	Riser sections including joints
	1B	Support ring for riser tensioning
	1A	Telescopic joint
	1B	Accumulators
	II	Hydraulic power unit including pumps and manifold
	II	Control panel
3. Heave compensation		
3.1 Tensioning system for riser and guidelines	1B	Riser tensioner
	1B	Guideline and podline tensioners
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system
	II	Air compressors
	II	Air dryers
	II	Wire ropes for tensioning equipment
	II	Sheaves for riser tension line
	II	Sheaves for guideline and podline
	1B	Telescopic arms for tension lines
	II	Control panels
3.2 Drill string compensator	1A	Compensator
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system including flexible hoses
	II	Air compressor
	II	Air dryer
	II	Wire ropes
	II	Sheaves
	II	Control panels
4. Hoisting rotation and pipe handling		
4.1 Drilling derrick	1A	Derrick and substructure
4.2 Hoisting equipment for derrick	1B	Sheaves for crown block and travelling block
	1A	Crown block including support beams

	1B	Guide track and dolly for travelling block
	1A	Travelling block
	1A	Drilling hook
	1A	Swivel
	1B	Links
	1B	Elevators
	II	Drilling line and sand line
	1B	Deadline anchor
	1B	Drawworks including foundation
	1B	Air winches for the transport of personnel
	1B	Cranes in derrick
	1B	Cherry picker
	1B	Personal hoisting equipment
4.3 Rotary equipment	1B	Rotary table including skid adopter and driving unit
	II	Kelly
	II	Master bushing
	II	Kelly bushing
	1A	Top drive
4.4 Pipe handling	1B	Racking arms with or without lifting head
	II	Finger board
	II	Tubular chute
	II	Hydraulic cathead
	II	Mousehole powered
5. Miscellaneous equipment for drilling	1B	Manual tongs for pipe handling
	II	Power tongs for pipe handling
	II	Kelly spinner
	II	Power slips
	1B	Elevators for lifting pipe
6. Bulk storage, drilling fluid circulation and cementing		
	1A	Drilling systems controls
	1B	Hydraulic control systems
	II	Hydraulic power units including ring lines
6.1 Bulk storage	1B	Pressurised storage vessels
	1B	Piping system for pressurised bulk transport
6.2 Drilling fluid, circulation and transportation		
6.2.1 Suction and transport System II	II	Piping systems for mixing of drilling fluid and suction line to the drilling fluid pump

(low pressure)	II	Centrifugal pumps for mixing drilling fluid
6.2.2 Well circulation system	1B	Drilling fluid pump – pressure side
(high pressure)	1B	Pulsation dampers
	1B	Piping circulation of drilling fluid in the well
	1B	Standpipe manifold
	1B	Rotary hose with end connections
	1B	Kelly cocks
	1B	Non-return valve in drill string (inside BCP)
	1B	Mixing pumps
	1B	Safety valves
	1B	Circulation head
6.2.3 Mud return system on deck	II	Mud return pipe
	II	Dump tank
	II	Shale shaker
	II	Drilling fluid tanks
	II	Trip tank
	II	Desander, desilter
	1B	Degasser
	1B	Piping from degasser to burners or to ventilation
	II	Chemical mixers
	II	Agitators for drilling fluid
6.2.4 Cementing	II	Centrifugal pumps for mixing of cement
	II	Piping system for mixing cement and suction line to the cement pump
	1B	Cement pump – pressure side
	1B	Pulsation dampener
	1B	Piping for cement pump discharge
	1B	Safety valves
7. Lifting system for blow out preventer	1A	Blow out preventer crane/carrier, etc.
8. Miscellaneous equipment being part of the drilling installations	*See Table 17.2.2 Miscellaneous equipment forming part of the drilling installation*	Miscellaneous pipes, flanges, valves, unions, etc.
	1B	Pressure vessels and separators
	1B	Heat exchangers
	1B	Pumps for overhauling of wells – pressure side
	II	Other pumps
	II	Burners
	1A	Burner boom

	See Table 17.2.2 Miscellaneous equipment forming part of the drilling installation	Safety valves for above equipment
NOTES 1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a drilling plant facility. 2. Equipment considered to be important for safety which is not listed in the Table will be specially considered by LR and categorised.		

2.2 Miscellaneous equipment

2.2.1 A list of miscellaneous equipment forming part of the drilling installation is given in *Table 17.2.2 Miscellaneous equipment forming part of the drilling installation*.

Table 17.2.2 Miscellaneous equipment forming part of the drilling installation

Component	Conditions	Category	
		1B	II
1. Piping	Thickness of wall > 25,4 mm.	X	
	Design temperature > 400°C	X	
	All welded pipes and piping systems used in Category 1A and 1B piping systems	X	
	Pipes other than those mentioned above and pipes in Category II systems		X
2. Flanges and couplings	Standard flanges and pipe couplings		X
	Non-standard flanges and pipe couplings used in Category 1A and 1B piping systems	X	
	Flanges and pipe couplings other than those mentioned above, and flanges and couplings for Category II piping systems		X
3. Valves	Valve body welded construction with ANSI rating > 600 lbs	X	
	Valves designed and manufactured in accordance with recognised standards		X
4. Components of high strength material	Specified yield strength > 345 N/mm_2 or tensile strength > 515 N/mm_2	X	

2.3 Production equipment

2.3.1 A list of usual production equipment with its categories is given in .

Table 17.2.3 Production equipment with its categories

Systems and types of equipment	Category	Description of equipment
1. Christmas tree and sub-sea production system	1A	Christmas tree, wellhead couplings, valves and control lines
	1A	Production manifolds and piping
	1B	Template and other floor structures
	1A	Well safety valve
	II	Electrical control module
2. Riser system		

2.1 Rigid	1A	Riser sections
	1A	Hydraulic connector unit
	1A	Ball and flexible joints
	1A	Telescopic joints
	1B	Support ring for tensioning system
	1B	Valves and actuators
	II	Inflection restrictors
2.2 Flexible	1A	Flexible riser
	1A	Connectors
	1B	Buoyancy elements
3. Riser tensioning system	1B	Riser compensator
	1B	Hydro-pneumatic accumulator
	1B	Pressure vessel
	1B	Pipe system
	II	Wire ropes
	II	Sheaves
	1B	Telescopic arm for wire ropes
	II	Control panel
	II	Air compressor with drier
4. Hoisting and handling equipment for rigid riser	1A	Derrick
	1A	Crown block with supporting beams
	1A	Travelling block
	1B	Hook
	II	Wire ropes
	1B	Air tuggers for personnel
	II	Air tuggers
	1B	Loose equipment for riser handling
	1A	Crane for handling production equipment

5. Oil production/processing equipment	1B	Production manifold with valves
	1B	Separator
	1B	Heat exchanger
	1B	Gas liquid separator/cleansers
	1B	Gas compressor (pressure side)
	1B	Dehydrators
	1B	Crude oil loading pumps
	1B	Crude oil and gas metering equipment
	1B	Gas liquid separator tanks
	1B	Glycol contactor
	II	Water injection pump (pressure side)
	1B	Glycol injection pump with equipment
	1B	Oil protection and process shut-down equipment
	1B	Valves and pipes
	1A	Flare system
	1A	Pig launcher/receiver unit
	II	Instrumentation and control equipment
	1A	Swivel for production
6. Pressure vessels (general)	1B	Pressure vessels
7. Miscellaneous equipment	1A	Flare booms
	1B	Burners
	II	Instrumentation components in general
8. For well overhaul and maintenance equipment, *see Pt 3, Ch 17, 2.2 Miscellaneous equipment 2.2.1*.	1B	Main instrumentation components and equipment in critical systems (e.g., control panels)
NOTES		
1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a production plant facility.		
2. Equipment considered to be important for safety which is not listed in the table will be specially considered by LR and categorised.		

2.4 Mechanical and electrical equipment

2.4.1 A list of mechanical and electrical equipment and its categories for units in the production, storage and offloading of liquefied gases in accordance with Part 11 is given in *Table 17.2.4 Mechanical and electrical equipment and its categories for units in the production, storage and offloading of liquefied gases in accordance with Part 11*.

Table 17.2.4 Mechanical and electrical equipment and its categories for units in the production, storage and offloading of liquefied gases in accordance with Part 11

Systems and types of equipment	Category	Description of equipment
1. Mechanical and electrical equipment certification required	1A	Boil off heater
	1A	Boil-off gas compressor
	1A	Turbo Expander
	1A	Gas heat exchanger
	1B	Burner
	1B	Flare
	1B	Cold vents
	1A	Columns – tray or packed type
	1A	Tensioning system
	1A	Structural bearings
	1A	Cold vent boom
	1B	Offloading hose
	1A	Offloading hose end valve
	1A	Pig launcher/receiver
	1A	Hawser strong point
	1A	Heat exchanger – Shell & tube, plate, annulus, printed circuit
	1A	High pressure LNG pumps for vaporiser
	1A	High pressure natural gas sent out system
	1A	High pressure natural gas vaporiser
	II	Pneumatic line thrower
	1B	Generators and motors over 100 kW
	1B	Uninterruptible power supplies, including battery chargers, with rating above 100 kVA
	1A	Unloading arms (rigid type) including couplings
	1A	Unloading arms (scissor, cantilever or A frame type) including couplings
	1B	Explosion protected equipment if not carrying a certificate from a recognised test institution
	1B	Filter strainers
	1B	Air dryers – regenerative type
	II	All other electrical equipment
	1B	Main control panels
	1A	Main storage tank discharge pumps
	II	Instrumentation components
	TA	Interbarrier space, insulation space or tank void relief valves
	1A	Gas turbines > 110 kW rating
	1A	Fire water pump skids (Package)

	1A	Gas compressor skid (Package)
	1A	Power generation skid
	1A	Steam turbines
	1A	Gears, shafts and couplings > 110 kW
	1A	Lifting appliances: see LR's *Code for Lifting Appliances in a Marine Environment* and hoisting and handling
	1A	Subsea facilities
	1A	Hydraulic and pneumatic power units
	1A	Flexible risers
	1A	Control umbilicals
	TA	Cryogenic storage tank relief valves
	1A	Storage tanks over 1000 L
	1A	Fired pressure vessels
	1A	Subsea systems
	1A	Substructure (cofferdam) heating system
	1A	Pressure vessels over 7 bar design pressure or 200ºF design temperature
	1B	Pumps – Rotary, positive displacement, mono
	1B	Quick release mooring hooks
	1B	Engines over 110 kW
	1A	Fire pumps and fire pump packages
	1A	Switchboards
	1A	Fixed fire-fighting system
	1A	Fixed fire and gas detection system
	1B	Utility pumps and air compressors
	1B	Valves - general
	1B	Expansion joint
	TA	Expansion joint in cryogenic services
	1B	Non standard valves
	1B	ESD valve and actuator
	TA	Expansion bellows
	1A	Christmas tree block and valves
	1A	HPU and pneumatic panels
	1A	Dynamic positioning system
	1B	IGS system
	TA	Cargo hoses
	1A	Cargo loading instrument
	1B	Chemical injection skid – pumps, vessels, measurement
	1A	Piping for Class I and Class II and boiler superheaters

	1A	Mooring winches and windlass
	1A	Nitrogen supply for storage tank containment system
	TA	Spark arrestors and vent heads, PV valves
	1A	Spray/circulation/supply pumps
	TA	Mooring chain
	TA	Hydraulic actuator
	TA	Anchor
	TA	GRE piping
	TA	Resins
	1B	Secondary or closed loop heating system for vaporiser
	1A	Slug catcher
	TA	Chokes
	1A	Winches and windlasses
	1A	Columns – tray or packed type
	TA	Communication equipment
	1A	Compressor – Centrifugal, rotary, reciprocating or screw
	TA	Fire and gas control panel and indicator
	TA	Master Mode switch
	TA	Fire hoses
	TA	Anodes
1. Marine system equipment to be built under survey as in*Pt 5, Ch 1, 1 General*	See Note	
	1A	Main propulsion engines including their associated gearing, flexible couplings, scavenge blowers and superchargers
	1A	Machinery and equipment for lowering deck structures of self-elevating units
	1A	Boilers supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, including superheaters, economisers, desuperheaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar (3,5 kgf/cm_2), and having heating surfaces greater than 4,65 m_2
	1A	Auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea
	1A	Steering machinery
	1A	Athwartship thrust units, their prime movers and control mechanisms
	1B	All pumps necessary for the operation of main propulsion and essential machinery, e.g., boiler feed, cooling water circulating, condensate extraction, fuel oil and lubricating oil pumps
	1A	All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g., air, water and lubricating oil coolers, fuel oil and feed water heaters, de-aerators and condensers, evaporators and distiller units
	1A	Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in *Pt 3, Ch 11, 1.6 Lifting padeyes*

	1A	Valves and other components intended for installation in pressure piping systems having working pressure exceeding 7,0 bar
	1A	Alarms and control systems as detailed in *Pt 6, Ch 1 Control Engineering Systems*and *Pt 7, Ch 1 Safety and Communication Systems*

NOTES

Items marked TA are to be type approved.

1. Category for gears, shafts and couplings is to be either 1A, 1B or II, depending on the category of the prime mover associated with the unit.

2. Fire water pump (directly driven) can be considered Category 1B. Fire water lift pump (not directly driven) of proven design may be accepted by conformation of material, witness of testing and review of fabrication documentation (1B). Fire water pump packages are to be built under survey (1A).

3. For complex machinery and equipment packages, categorisation and approval procedure to be agreed with on a case by case basis, considering selection of materials, service and complexity of design and fabrication method.

4. The approval procedure to be agreed with on a case by case basis, depending on function and criticality. See relevant Rule requirements, AS 4343, EC directives, Regulatory requirements, specific purchaser requirement.

Additional Notes for classed pressure vessel requirements. *See also* Pt 5, Ch 10,1.6.

Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g., air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and

$pV > 600$

$p > 1$

$V > 100$

V = volume (litres) of gas or vapour space.

(b) The vessel contains liquefied gases, for fire-fighting or flammable liquids, and

$p > 7$

$V > 100$

V = volume (litres).

Section 1
Survey requirements

1.1 Application

1.1.1 The information in this Appendix is intended to provide guidance to Owners and Surveyors for the inspection of classed positional mooring systems as defined in Chapter 10.

1.2 Annual Surveys

1.2.1 Annual Surveys are to be carried out in accordance with *Pt 1, Ch 3 Periodical Survey Regulations* with the vessel at its normal operational draft with the positional mooring system in use.

1.2.2 The purpose of the Annual Survey is to confirm that the mooring system will continue to carry out its intended purpose until the next Annual Survey. No disruption of the unit's operation is intended. Where practicable the Annual Survey is to be carried out during a relocation move.

1.2.3 The scope of the Annual Survey is limited to the mooring components adjacent to winches, windlasses and fairleads. Depending on the mooring component visible from the unit, particular attention should be given to:

(a) Chain:

- Wear in the chain shoulders in way of the chain stopper, windlass pockets and fairleads.
- Support of chain links in the windlass pockets.

(b) Wire rope:

- Flattened ropes.
- Broken wire.
- Worn or corroded ropes.

1.2.4 The Surveyor should examine the maintenance records and determine if any problems have been experienced with the mooring system in the previous twelve months, e.g., breaks, mechanical damage, loose joining shackles, and chain or wire jumping.

1.2.5 Should the Annual Survey reveal severe damage or neglect to the visible chain or cable, a more extensive survey will be required by Lloyd’s Register (hereinafter referred to as ‘LR’).

1.2.6 Typical damage warranting a more comprehensive survey would include:

(a) Chain:

- Reduction in diameter exceeding 75 per cent of the margin assumed in the design, *see Pt 3, Ch 10, 8.2 Corrosion and wear*
- Missing studs.
- Loose studs in Grade 4 chain.
- Worn lifters (i.e., gypsies) causing damage to the chain.

(b) Wire rope:

- Obvious flattening or reduction in area.
- Worn cable lifters causing damage to the wire rope.
- Severe wear or corrosion.

1.3 Special Surveys

1.3.1 Special Periodical Surveys are to be carried out at five-yearly intervals in accordance with *Pt 1, Ch 3 Periodical Survey Regulations*, and will require extensive inspection, usually associated with a sheltered water visit. When considered necessary by LR the interval between Special Periodical Surveys may be reduced.

1.3.2 The purpose of the Special Survey is to ensure that each anchor line is capable of performing its intended purpose until the next Special Survey, assuming that appropriate care and maintenance is performed in the mooring system during the intervening period.

1.3.3 The Special Survey should include:

(a) Close visual inspection (100 per cent) of mooring chains, with cleaning as required.
(b) Enhanced representative NDT sampling.
(c) Dimension checks.

1.3.4 Particular attention is to be given to the following:

- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches, windlass and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

1.3.5 This survey is to ensure that the lengths of anchor line frequently in contact with winches, windlasses and fairleads are suitably rated for this application.

1.3.6 Joining shackles are to be examined for looseness and pin securing arrangements. All joining shackles of the Kenter type and bolted type which have been in service for more than four years should be dismantled and an MPI performed on all machined surfaces as per *Pt 3, Ch 17, 2.6 Inspection of miscellaneous fittings*.

1.3.7 Visual surveys of all windlass and fairlead chain pockets are to be carried out with particular attention to the following:

- Unusual wear or damage to pockets.
- Rate of wear on pockets including relative rate of wear between links and pockets.
- Mismatch between links and pockets, and improper support of the links in the pockets.

1.3.8 The thickness (diameter) of approximately one per cent of all chain links should be measured. The selected links should be approximately uniformly distributed through the working length of the chain. The above percentage may be increased/decreased if the visual examination indicates excessive/minimal deterioration.

1.3.9 A functional test of the mooring system during anchor-handling operation is to be carried out with particular attention given to the following:

- Smooth passageway of chain links and or/wire rope and joining shackles over the windlass and fairleads pockets.
- The absence of chain jumping or other irregularities.

1.4 Special Continuous Surveys

1.4.1 As an alternative to the Special Survey, the Owner may agree with LR that the Special Survey may be carried out on a continuous survey basis by providing an extra mooring line which may be regularly inspected on shore and exchanged with lines installed on the unit in accordance with an appropriate schedule.

Section 2
General guidelines on inspection of mooring system components

2.1 Anchor inspection

2.1.1 The anchor head, flukes and shank are to be examined for damage, including cracks or bending. The anchor shackle pin should be examined and renewed if excessively worn or bent. Moveable flukes should be free to rotate.

2.1.2 Bent flakes or shank should be heated and jacked in place according to an approved procedure, followed by Magnetic Particle Inspection.

2.2 Anchor swivels

2.2.1 Although swivels are no longer in common use, anchors have been lost due to corrosion of the threads engaging the swivel nut. Swivel nut threads should be carefully examined and if significant corrosion is found, the swivel should be removed or replaced.

2.3 Chain inspection criteria

2.3.1 This sub-Section applies only to 'Offshore' or 'Rig Quality' chains with studs secured by one of the following means:

- Mechanically locked in way of the link's flash-butt weld and fillet welded on other end (IACS R3 chain for example); or
- Studs mechanically locked in place on both ends (IACS R4 chain for example).

Other types of chain will require special consideration.

2.3.2 The service environment of offshore mooring chain is more severe than the service environment for conventional ship anchoring chain. Offshore chain is exposed to service loads for a much longer period of time. The long-term exposure to cyclic loadings in sea-water magnifies the detrimental effect of geometric and metallurgical imperfections on fatigue life. Moreover, the increased number of links in offshore chains renders the chain more susceptible to failure from a statistical standpoint.

2.3.3 Due to the effect of notches, e.g., the stud footprint, higher strength steels such as that used for IACS R4 chain have a lower ratio of fatigue strength to static tensile strength than typical lower strength steel such as used for IACS R3 chain.

2.3.4 Since chain link diameter loss can be due to abrasion and corrosion, diameter measurements should be taken in the curved or bend region of the link and any area with excessive wear or gouging. Two diameter measurements should be taken 90 degrees apart. Particular attention should be given to the shoulder areas which normally contact the windlass or fairlead pockets.

Links should be rejected if the minimum crosssectional area is less than the minimum Rule chain size plus a margin for corrosion and wear between surveys, see *Pt 3, Ch 10, 8.2 Corrosion and wear*. If repair is permitted it should be done by qualified personnel using an approved procedure.

NOTE

WELD REPAIR IS NOT PERMITTED ON IACS R4 CHAIN (*see* B2.3.6).

Two diameter measurements should be taken 90 degrees apart.

2.3.5 Since studs prevent knots or twist problems during chain handling and support the sides of the links under load to reduce stretching and bending stresses, missing studs are not acceptable. Links with missing studs should be removed or the studs should be refitted using an approved procedure.

2.3.6 Where chain studs are secured by fillet welds on one end, the stud is likely to fall out if a stud is loose or the weld is cracked. Any axial or lateral movement is unacceptable and the link must be repaired or replaced.

Links with studs fillet welded on the flash-butt weld end of the stud are unacceptable.

Rejection of links with gaps exceeding 3 mm between the stud and the link at the flash-butt weld end of the stud should be considered. Closing the gap by renewing the fillet weld may be considered but *see* the note in B2.3.8.

2.3.7 Field repair of cracked welds should be avoided if at all possible. Welding must be performed by qualified personnel using approved procedures:

NOTE

WELD REPAIR IS NOT PERMITTED IN IACS R4 CHAIN.

Chains with studs mechanically locked in place on both ends may only be repaired by an approved mechanical squeezing procedure to reseat the stud.

2.3.8 Fillet welding of studs in both ends is not acceptable; nor is welding on the stud end adjacent to the link's flash-butt weld.

Existing studs with fillet welds on both ends will require special consideration and will be subject to special crack detection methods. A reduction in mechanical properties in way of the flash-butt weld will normally be required.

2.3.9 Where chain studs are secured by press-fitting and mechanical locking, it is very difficult to quantify excessive looseness of chain studs. The decision to reject or accept a link with a loose stud must depend on the Surveyor's judgement of the overall condition of the chain complement.

Axial movement of studs of 1 mm or less is acceptable. Links with axial movement greater than 2 mm must be replaced by squeezing or removed. Acceptance of chain links with axial movements from 1 to 2 mm must be evaluated based on the environmental conditions of the unit's location and expected period of time before the chain is again available for inspection.

Lateral movement of studs up to 4 mm is acceptable.

2.3.10 Where links are damaged and have cracks, gouges and other surface defects (excluding weld cracks), they may be removed by grinding, provided B2.3.4 is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.
(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.
(c) Since joining shackles have much lower fatigue lives than ordinary chain links, as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.
(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

2.4 Fairlead and windlass inpsection - Chain system

2.4.1 Fairlead inspections should verify that all fairleads move freely about their respective pivot axes, to the full range of motion required for their proper operation. All bolts, nuts and other hardware used to secure the fairlead shafts should be inspected and replaced as required.

Fairlead attachment to the hull should be verified and NDT conducted as necessary.

NOTE

There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

2.4.2 Special attention should be given to the holding ability of the windlasses. The chain stopper and the resultant load path to the unit's structure should be inspected and its soundness verified.

2.4.3 It is essential that a link resting in a chain pocket makes contact with the fairlead at only the four shoulder areas of the link to avoid critical bending stresses in the link. Satisfactory chain support is to be verified, and excessive wear in the pockets should be repaired as required to prevent future damage to the chain.

2.4.4 Chain pockets may be repaired by welding in accordance with the standard procedures supplied by the fairlead/ windlass manufacturer. Normally, the hardness of the pockets should be slightly softer than the hardness of the chain link and procedures must be specific for the chain quality used.

2.5 Fairleads and windlass – Wire rope systems

2.5.1 Fairleads are to be inspected in accordance with B2.4.1.

2.5.2 Special attention should be given to the holding ability of the winch and the satisfactory operation of the pawls, ratchets and braking equipment. The soundness of the resultant load path to the unit's structure should be verified.

Proper laying down of the wire on the winch drum should be verified to the satisfaction of the Surveyor and drums and spooling gear adjustments made if required.

2.6 Inspection of miscellaneous fittings

2.6.1 Anchor shackles, large open links, swivels and connecting links should be visually inspected. Certain areas should be examined by MPI. Areas to be examined should be clearly marked on each item. Links and fittings should be dismantled as required. Damaged items should be replaced as required by the attending Surveyor. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance on the areas requiring MPI is listed as follows:

- Large open links: the interior contact surfaces of large open links.
- Bolted shackles: the inside contact areas and the pins.
- Swivels: the swivel pin and threads and mating surface.

2.6.2 Experience has shown that large numbers of anchors and chains are lost in service due to connecting link failure. Fatigue problems have resulted from poorly designed machined faces and corners. Joining shackles of Kenter or similar designs manufactured before 1984 are of particular concern. Joining shackles used for higher strength chains, such as ORQ and above, which do not have certificates of equivalent quality should be rejected.

2.6.3 All joining shackles of Kenter or similar design which have been in service for more than four years should be dismantled and MPI carried out. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance in the areas requiring MPI is listed as follows:

- Joining-shackle links: all machined and ground services of the link and the sides of the curved portions of the link.
- Joining-shackle stud: machined surfaces only.
- Joining-shackle pin: 100 per cent.

Fatigue is considered to be the critical criterion in way of the machined surfaces. On the remaining surface, the profile should be ground smooth and MPI should be carried out upon completion of grinding. In general, the radius of the completed grinding operation should produce a recess with a minimum radius of 20 mm and a length along the link bar greater or equal to six times its depth.

NOTE

Sandblasting prior to MPI may change the machined surfaces and should be avoided. Alternative methods of cleaning should be used.

Where links are damaged and have cracks, gouges or other surface defects (excluding weld cracks), they may be removed by grinding, provided *Pt 3, Ch 17, 2.3 Chain inspection criteria* is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.
(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.
(c) Since joining shackles have much lower fatigue lives than ordinary chain links as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.
(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

2.6.4 Tapered pins holding the covers of connecting links together should make good contact at both ends and the recess of counterbore at the large end of the pin holder should be solidly plugged with a peened lead slug to prevent the pin from working out.

2.6.5 Any joining shackles of Kenter or similar designs which are loose upon reassembly should be rejected.

2.7 Wire rope

2.7.1 Acceptance criteria should be guided by ISO-Standard 4309-1981(E). Further insight may be gained from the discard guidance provided by API RP 2I, Figures 18 and 19.

2.7.2 It should be borne in mind that ISO-Standard 4309-1981(E) is primarily intended for lifting appliances where the Factor of Safety may be higher than for mooring wires.

2.7.3 The Surveyor should exercise great care in his interpretation of the condition of the wire. An obvious acceptance or rejection is comparatively easy, but the grey area between is difficult to evaluate. The Surveyor must make a sound evaluation and technical judgement based on all available evidence.

2.7.4 In general, the age or time in service of the wire does not directly have a bearing on the acceptance or rejection of the wire other than as a factor to be taken into consideration by the Surveyor when deciding on the extent of the survey.

2.7.5 100 per cent visual examination of wire ropes is to be carried out and diameter measurements should be performed.

2.7.6 Visual examination should identify and record the following items for each steel wire anchor line:

(a) The nature and number of wire breaks:

- Wire breaks at the termination.
- External wear and corrosion.
- Localised grouping of wire breaks.

(b) Deformation:

- Fracture of strands.
- Termination area.
- Reduction of rope diameter, including breaking or extrusion of the core.

2.7.7 Diameter measurements should be taken at approximately 110 metre intervals, at the discretion of the attending Surveyor. If areas of special interest are found, the survey may be concentrated on these areas and diameter measurements taken at much smaller intervals.

2.7.8 An internal examination should be undertaken as far as practicable if there are indications of severe internal corrosion or possible breakage of the core or wire breaks in underlying areas. *See* API RP 2I, Section 2.3.6.3, for guidance on the internal inspection of wire rope.

2.8 Guidance on wire rope damage

2.8.1 The cause of wire rope failures may be deduced from the observed damage to the rope. The information summarised in this sub-Section covers most types of wire rope failure. More detailed information, including photographic examples, is available in ISO-Standard 4309-1981(E) and API RP 2I.

2.8.2 Broken wires at the termination indicate high stresses at the termination and may be caused by incorrect fitting of the termination, fatigue, overloading, or mishandling during deployment or retrieval.

(a) Distributed broken wires, illustrated by Figures 9 to 12 of API RP 2I, may indicate the reason for their failure:

- Crown breaks or breakage of individual wire at the top of strands may be caused by excessive tension, fatigue, wear or corrosion.
- Excessive tension is indicated by necking down of the broken end of the wire.
- Fatigue is indicated by broken faces perpendicular to the axis of the wire.
- Corrosion and wear may be indicated by reduced cross-sections of the wire.
- Valley breaks at the interface between two strands indicate tightening of the strands, usually caused by a broken core or internal corrosion which has reduced the diameter of the core.
- Valley breaks can be caused by high loads, tight sheaves of too small a diameter.

(b) Locally grouped broken wires in a single strand or adjacent strand may be due to local damage. Once begun, this type of damage will usually get worse.

2.8.3 Changes in rope diameter can be caused by external wear, interwire and interstrand wear, stretching or corrosion. A localised reduction in rope diameter may indicate a break in the core. Conversely, an increase in rope diameter may indicate a swollen core due to corrosion.

2.8.4 Wear on the crown of outer strands in the rope may be caused by rubbing against fairleads, unit structure or the sea bed, depending on the location of the wear. Internal wear between individual strands and wires in the rope is caused by friction and is accelerated by bending of the rope and corrosion.

2.8.5 Corrosion decreases rope strength by reducing the cross-sectional area and accelerates fatigue by creating an irregular surface which invites stress cracking. Corrosion is indicated by:

(a) The diameter of the rope at fairleads will grow smaller.

(b) The diameter of stationary ropes may actually grow larger, due to rust under the outer continuous layer of strands. Diameter growth is rare for mooring lines.

2.8.6 Deformation, i.e., distortion of the rope from its normal construction, may result in an uneven stress distribution in the rope. Kinking, bending, scrubbing, crushing, and flattening are common wire rope deformations. Ropes with slight deformations will not lose significant strength. Severe distortions can accelerate deterioration and lead to premature failure.

2.8.7 Thermal damage, although rare for mooring ropes in normal service, may be indicated by discoloration. Prompt attention should be given to damage caused by excessively high or low temperatures. The effect of very low temperatures on wire rope is unclear except for the known detrimental effect on lubricants.

■ *Section 3* **Cross-references**

3.1 Wire rope

3.1.1 API RP 2I and ISO-Standard 4309-1981(E)

(Please note comment in B2.7.2 regarding the ISO-Standard)

3.2 Chain

API RP 2I '*Recommended Practise for In-service Inspection of Mooring Hardware for Floating Drilling Units*'.

Section 1
Introduction

1.1 Application

1.1.1 This document has been extracted from standard LR Group Oil and Gas project Verification Work Instructions, for issue as part of the LR Quality System and should be read in conjunction with Project-Specific Quality Plan and supporting procedures. It is intended to outline appropriate scopes of survey for typical safety critical items of equipment associated with disconnectable or mobile drilling and production installations where LR is providing Certification or Verification/Validation services. The list is not exhaustive and should be used as a guide for equipment which is to be included within the scope of the service to be provided. The extent to which the Surveyors are required to attend in order to ensure that each item of equipment complies with a recognised Code, specification, or agreed Standard of performance is to be agreed with LR. The attendance required will be indicated on the supplier's Inspection and Test plan as a minimum. The procedures between Project Vendors and their local LR Surveyors are to be agreed.

1.1.2 Some typical acceptable Codes and Standards are referenced herein. Other National or International Standards may be considered and accepted if deemed appropriate by LR. Company standards may also be applied where they represent an agreed standard of performance. *See also Pt 3, Ch 17, 1 Codes and Standards*.

1.1.3 Where equipment is identified as being safety critical to an installation, survey/examinations undertaken within their examination schemes or codes may be considered to contribute to the validation required of such equipment. Safety critical equipment/elements are those such parts of an installation and such parts of its plant (including computer programs), or any part thereof;

(a) The failure of which could cause or contribute substantially to; or
(b) A purpose of which is to prevent, or limit the effect of, a major accident.

Section 2
Scope of survey for equipment

2.1 Accommodation/temporary refuge units

2.1.1 Design appraisal and survey of structure, pipework, HVAC arrangements, and fire and overpressure protection is required. *See also* C2.37 and C2.41.

2.2 Accumulators

2.2.1 *See* C2.29.

2.3 Air receiver and drier vessels

2.3.1 Where the maximum air pressure is equal to 7 barg (100 psi) or greater, a survey to Code requirements including design appraisal is required.

2.3.2 Where the pressures are less than 100 psi, valid manufacturers' documentation can be accepted. Material is to be manufactured to a recognised pressure vessel standard.

2.3.3 Typical acceptable standards: BS 5169, ASME VIII Div. 1 and BS 5500.

2.4 Air winches

2.4.1 *See* C2.33.

2.5 Blast rated boundaries/enclosures

2.5.1 Design appraisal for rated blast overpressure and construction under survey is required.

2.6 Blow out preventers and BOP control unit

2.6.1 *See* C2.57.

2.7 Burner (flare) booms or towers

2.7.1 Design appraisal is required with respect to:

(a) Environmental loads.
(b) Loads onto platform unit.
(c) Location and length with respect to heat radiation hazard.
(d) Construction under survey.

2.7.2 Typical acceptable Standards are Structural Design A.I.S.C., Fabrication AWS D1.1, BS 4870, BS 4871 and Heat Radiation API RP 521.

2.8 Coolers/chillers

2.8.1 *See* C2.25.

2.9 Compressors/compressor packages

2.9.1 Reciprocating machines above 100 kW are to be built under survey with design appraisal of piping systems, any contained pressure vessels and torsional vibration characteristics for large reciprocating machines. Hydrostatic tests to be witnessed and manufacturers' data examined for other components. *See also* C2.53 and C2.55.

2.10 Cranes

2.10.1 *See* C2.33.

2.11 Deluge systems

2.11.1 Review of P&IDs, hydraulic calculations, area coverage and pump capacities is required. For survey, *see* C2.12, C2.41 and C2.45.

2.12 Diesel prime movers

2.12.1 For air compressors, mud pumps, cement pumps, generators and drawworks except fire.

2.12.2 Pumps and emergency generators.

2.12.3 Design appraisal with respect to vibration (i.e., hazardous areas), torsional vibration characteristics of shaft system and witness of commissioning of machines is required.

2.12.4 For fire pumps, vessel propulsion, auxiliary service and emergency generators.

2.12.5 Survey is required where the power is equal to or in excess of 100kW and to include above. If power is less than 100kW, manufacturers' documentation can be accepted. Engines should be suitably marinised, batch and line approved and able to operate under the conditions specified in LR Rules.

2.13 Distillation plants

2.13.1 *See* C2.25.

2.14 Drums

2.14.1 *See* C2.43.

2.15 Electrical equipment

2.15.1 Survey at manufacturers' works is not required for equipment that is not specified in LR Classification Rules requirements. Equipment must be manufactured in accordance with a recognised Standard and manufacturers' certificates are required. Flameproof and I.S. equipment is to be supplied with relevant certification and documentation issued by a recognised authority and must be suitable for the application. After installation under survey, the integrity of the complete system is to be established.

2.16 Emergency shut-down systems/fire and gas systems

2.16.1 Witness of testing and documentation review at suppliers' works by a specialist LR Surveyor is recommended (mandatory where full Cause and Effect Testing is not repeated during the installation commissioning phase).

2.16.2 Design appraisal requirements will vary according to the responsibilities assigned to the supplier by the main design contractor. For programmable systems, details of Hardware, system specification and Software QA manuals will be required for review. (Process control systems do not require LR survey at suppliers' works).

2.17 Fans

2.17.1 Survey at manufacturers' works is not required. Manufacturers' documentation to be supplied.

2.17.2 When intended for use in hazardous areas, fans must be of non-sparking type.

2.18 Filters

2.18.1 *See* C2.43.

2.19 Fire and foam pumps

2.19.1 *See* C2.12.

2.20 Flare booms and towers

2.20.1 *See* C2.7.

2.21 Flexible hoses

2.21.1 Manufacturers' documentation, including prototype burst testing is required. Fire test certification is generally required for hydrocarbons, high pressure and essential control service.

2.22 Fluid transfer systems (fluid swivel type)

2.22.1 Strength design appraisal and survey during manufacture, assembly and test is required.

2.23 Gas turbines/compressors

2.23.1 *See* C2.53.

2.24 Geared machinery

2.24.1 Witness of commissioning and testing after installation is required.

2.25 Heat exchangers

2.25.1 **Hydrocarbons**. Design appraisal and survey during manufacture to Code requirements is required.

2.25.2 **Non-hydrocarbons**, Design pressures greater than or equal to 7 barg (100 psi). Design appraisal and survey during fabrication is required. *See also* C2.43, which applies equally to shell and tube exchangers.

2.25.3 **Non-hydrocarbons**. Design pressures less than 7 barg (100 psi). Manufacturers' documentation can be accepted with hydrostatic tests being witnessed after installation. Material is to be manufactured to a recognised pressure vessel standard.

2.25.4 Typical acceptable codes: PD 5500, ASME VIII Div. 1 & 2 and TEMA Standards.

2.26 Helideck

2.26.1 Design appraisal of structure, markings, lights, obstacle free/drop off zones, fire and escape arrangements is required. Survey under fabrication as for modules.

2.27 Hoists

2.27.1 *See* C2.33.

2.28 Hydrocyclones

2.28.1 Survey at manufacturers' works is not required for proprietary drilling equipment.

2.28.2 *See Pt 3, Ch 17, 2.43 Pressure vessels*.

2.29 Hydro-pneumatic accumulators – Manifolds, fluid reservoirs

2.29.1 Design appraisal and construction under survey is required.

2.29.2 Typical acceptable standards: BS 5045 and ASME VIII Div. 1.

2.30 Impressed current CP system

2.30.1 Design appraisal. Survey of installation, witness test and commissioning are required.

2.31 Inert gas generator

2.31.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

2.32 Lifeboats, TEMPSCs, rescue craft and davits

2.32.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

2.33 Lifting appliances and cranes

2.33.1 To be built under survey in accordance with the LR's Code for Lifting Appliances in a Marine Environment, which would include design appraisal, material identification, weld procedures and welder qualification tests, approval of NDT procedures and testing on completion. Care is to be taken that the appliance is suitable for use under dynamic loading offshore.

2.33.2 Air winches (non-personnel). No survey required at source. Manufacturers' documentation will be accepted provided it includes evidence of hydrostatic test of pressure parts.

2.33.3 Cranes mountings, including pedestals. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

2.33.4 Other typical acceptable construction codes are given in *Pt 3, Ch 17, 1.2 Recognised Codes and Standards*.

2.33.5 Personnel hoist. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

2.33.6 Other lifting devices. Where LR Certification is required by the client, design appraisal and survey with load testing after installation on the platform/unit is required.

2.33.7 Other lifting devices. Where LR Certification is not required, inspection and testing at the manufacturers' works is required only for devices with a capacity greater than or equal to 10 tonnes. Devices with a capacity of less than 10 tonnes can be accepted if presented with valid manufacturers' documentation. In addition, they must be tested after installation.

2.34 Loading instrument

2.34.1 To be verified for LR Classification compliance – *see Pt 1 REGULATIONS*. Hardware to be type approved for marine use.

2.35 Manifolds, choke, production, test, etc.

2.35.1 Design appraisal and survey is required.

2.35.2 Typical acceptable standards: ANSI B3 1.3.

2.36 Metering packages and equipment

2.36.1 To be built under survey with design appraisal of piping systems aspects and any pressure vessels. Hydrostatic test to be witnessed and manufacturers' data examined for all other aspects.

2.37 Modules (all types)

2.37.1 Design appraisal and survey of structure during construction is required and the following loads should be considered in the design.

(a) Environmental.
(b) Equipment and operational weights.
(c) Construction, including lifting case.

2.37.2 *See also* C2.41.

2.38 Mooring systems (floating installations)

2.38.1 Structural. Design appraisal and survey during manufacture is required for all components, including anchors, cables, chains, turret structure, etc.

2.38.2 Machinery. Design appraisal is required for all main bearings, mooring winches and chain stoppers.

NOTE:

Quayside mooring equipment can be accepted on the basis of manufacturers' documentation.

2.39 Offloading systems

2.39.1 *See Pt 3, Ch 17, 2.21 Flexible hoses*, C2.41 and C2.46.

2.39.2 Strength design appraisal of mooring winches, breakaway couplings, etc., is required.

2.40 Pig launchers and receivers

2.40.1 *See* C2.43.

2.41 Pipework and fittings

2.41.1 All fabricated pipework, e.g., process systems, gas and liquid fuel systems, fire main, compressed air lines, hydraulic systems, mud systems, etc., will be subject to design appraisal and survey during fabrication. Pipe fittings will normally be accepted with manufacturers' documentation, but significant fabricated items may require survey at manufacturers' works. Fabricated saddles for use in the fire main should be supplied with a copy of a valid proof test certificate.

2.41.2 The survey must include:

(a) Review of QA/QC system.
(b) Examination at works during fabrication and test.
(c) Review and acceptance of weld procedures and welder qualification tests.
(d) Review and acceptance of NDT procedures.
(e) Verification of materials against relevant mill certificates.
(f) Appraisal of P&IDs, material and pipe schedules.

2.41.3 Where pipework is included as part of a package, it is to be surveyed as above.

2.41.4 Typical acceptable standards: ANSI B3 1.3.

2.42 PLCs/programmable electronic systems

2.42.1 Hardware to be type approved for offshore use. Software to be developed under suitable software QA system. LR to witness commissioning tests.

2.43 Pressure vessels

2.43.1 (Separators, knockout drums, pulsation dampers, etc., including auto sprinkler and fire-extinguishing storage systems).

2.43.2 Where the system gauge pressure in bar multiplied by the internal volume in litres exceeds 200, vessels are to be built under survey which would include design appraisal, material identification, weld procedure and welder qualification tests and approval of NDT procedures. The vessel is to be built in accordance with a recognised Code or Standard and subject to hydrostatic test and internal examination on completion.

2.43.3 Typical acceptable codes: PD 5500 and ASME VIII.

2.44 Process equipment (bulk)

2.44.1 All equipment, whether installed initially or at a subsequent date, should be manufactured to a relevant Code, Standard or specification and written confirmation of this, together with appropriate test certificates, should be obtained from the manufacturer. *See* C2.41 and the remainder of this appendix for individual equipment items.

2.45 Pumps – Fire, water deluge, foam, etc.

2.45.1 All fire-fighting pumps (and prime movers) to be built under survey.

2.45.2 Material certificates and certificates for hydrostatic testing of cast casings, etc., to be reviewed.

2.46 Pumps for other services

2.46.1 Survey at manufacturers' works for verification purposes is not required. Manufacturers' documentation including material certificates is to be supplied.

2.47 Radio tower

2.47.1 Design appraisal will be required only in respect of:

(a) Environmental loads.
(b) Loads transmitted to the structure.
(c) Location relating to the helideck.

2.47.2 No fabrication inspection is required.

2.48 Regenerators and absorbers, glycol – (fired) boilers and steam receivers – (fired)

2.48.1 Design appraisal and survey is required, *see also* C2.43 and C2.25.

2.49 Separators

2.49.1 *See* C2.43.

2.50 Steel – Plate, rolled sectors, tubulars and pipe

2.50.1 For certification, inspection/validation at mill in accordance with a recognised Standard and specification is required on all material for primary structures. However, certification of other IACS members will in general be acceptable.

(a) Jackets including conductor framing.
(b) Piles.
(c) Any secondary steel that is connected directly to the primary structure.
(d) Any structural steel utilised for the load-bearing framework of the module.
(e) Where floors contribute to the strength and integrity of the module. Where steel is procured from steelworks approved by LR, our scope will normally be limited to witness of mechanical testing and check of results against agreed specifications. In the event of primary steel being procured from stockists, LR involvement will normally consist of verification of test certificates, material identification and confirmation of properties against agreed specifications.

2.50.2 Materials for secondary structures need not be inspected at source provided the material is manufactured in accordance with a recognised Standard and is supported by manufacturers' valid mill certificates.

2.50.3 Examples of secondary structures include gangways, walkways, handrails, cladding, helideck, floors, pipe supports, equipment plinths, mud and similar tanks and installation aids.

2.51 Strainers

2.51.1 *See* C2.43.

2.52 Tanks

2.52.1 Dry mud, barytes, bulk cement, chemicals:

(a) Design appraisal and survey is required if the above tanks are to be subjected to any positive or negative pressure conditions.
(b) If not pressurised, the Surveyors may accept a Third Party Inspection Certificate with evidence of testing for the purpose intended.

2.52.2 Non hazardous liquid storage tanks – Open, vented or hydrostatic head only. Third party Inspection Certificate with evidence of construction and testing to a recognised Code or specification is required.

2.52.3 Pressurised lubricating oil or seal-oil tanks. Design appraisal and survey is required.

2.52.4 Fuel tanks and hazardous liquid tanks. Design appraisal and survey is required. Typical acceptable standards: BS 799 part IV and BS 2654.

2.53 Turbines and compressors

2.53.1 Design pressure greater than or equal to 7 barg (100 psi). Surveyor is to verify manufacturers' documentation, witness hydraulic tests of pressure parts and commissioning of machines.

2.53.2 Design pressure less than 7 barg (100 psi). Surveyor is to verify manufacturers' documents and witness commissioning. Material is to be manufactured to a recognised pressure vessel standard.

2.53.3 Gas turbines. Consideration should be given to the codes used for pressure-retaining components and the need for containment, with a view to minimising and localising damage in the event of rotor blade failure. Survey of fabricated pressure-retaining items will generally be required.

2.54 Umbilicals for subsea completion control systems

2.54.1 Design appraisal and survey at source to include review of manufacturing and quality plans is required. Witness of factory acceptance tests and documentation review is also required.

2.55 Valves including emergency shut-down and safety valves

2.55.1 In general, valves and fittings need not be surveyed at source provided they are manufactured in accordance with a recognised Code or Standard and are identifiable with a manufacturers' certificate which includes the materials used for pressure-containing parts.

2.55.2 Details of certain large valves and fittings of welded construction will require to be submitted for special consideration, (e.g., Riser ESDVs, SSIVs, etc.). Design appraisal and survey of these items will be required in most cases.

2.55.3 Testing of pressure relief valves to be witnessed during commissioning at fabrication sites.

2.55.4 Typical acceptable standards: Safety Valve Design API RP 520, Valves API 6 series, B55351 and Fittings BS 1640.

2.56 Ventilation and pressurisation systems including fire dampers

2.56.1 Design appraisal: hazardous area zones and structural fire protection. The systems are to be surveyed and tested during installation and commissioning.

2.56.2 Fire Dampers are to be type approved.

2.57 Well control equipment

2.57.1 Independent Review Certificate from a Certifying Authority is to be issued for manufacture and design. Surveyors will issue a Certificate of Conformity following completion of the equipment and when satisfied that the equipment has been built and tested in accordance with the approved Specification for Manufacture. Manufacturers' records of materials, inspection and tests should be assessed by the Surveyor.

2.57.2 For Verification (Wells Examination). Well control equipment will be subject to a design examination and survey during construction/assembly and testing where the equipment is designated as safety critical to the Installation.

2.57.3 Work done by others to meet the requirements of the well examination scheme will contribute to verification.

2.58 Well control panel

2.58.1 Design appraisal and survey, as for pipework and fittings.

2.59 Winches

2.59.1 *See* C2.33.

2.60 Xmas trees

2.60.1 *See* C2.58.

Contents

■ *Section 1* Rule application

1.1 General

1.1.1 The Rules, in general, apply to steel units of all welded construction. The use of other materials in the structure will be specially considered. For concrete structures, *see Pt 9 CONCRETE UNIT STRUCTURES*. The Rules apply to the unit types defined in *Pt 1 REGULATIONS* and *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*. Units of unconventional design will receive individual consideration based on the general standards of the Rules.

1.2 Loading

1.2.1 The Rules are framed on the understanding that units will be properly loaded and operated. Units are to be operated in accordance with an Operations Manual which is to contain all the necessary information for the safe loading and operation of the unit, *see Pt 3, Ch 1, 3 Operations manual*.

1.2.2 All ship units and other surface type units are to be provided with loading guidance information containing sufficient information to enable the loading, unloading and ballasting operations and inspection/maintenance of the unit within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in *Pt 3, Ch 4, 8 Loading guidance information* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). *See also Pt 1, Ch 2, 1.4 General 1.4.5* and *Pt 1, Ch 2, 1.4 General 1.4.6*.

1.2.3 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided, the system is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.3 Advisory services

1.3.1 The Rules do not cover certain technical characteristics such as stability, trim, vibration, docking arrangements, etc. The Classification Committee cannot assume responsibility for these matters, but is willing to advise upon them on request.

1.4 Intact and damage stability

1.4.1 New units will be assigned class only after it has been demonstrated that the level of intact and damage stability is adequate, *see Pt 1, Ch 2, 1 Conditions for classification*.

1.4.2 For classification purposes, the minimum requirements for watertight and weathertight integrity are to comply with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

Section 2
Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be submitted in support of alternative arrangements and scantlings. LR may undertake independent calculations to check the calculations submitted by the designers.

2.2 Equivalents

2.2.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

2.2.2 Where direct calculation procedures are employed supporting documentation is to be submitted for appraisal and this is to include details of the following:

- Calculation methods, assumptions and references.
- Loading.
- Structural modelling.
- Design criteria and their derivation, e.g., permissible stresses, factors of safety against plate panel instability, etc.

2.2.3 LR will be ready to consider the use of Builders' programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

Section 3
National and International Regulations

3.1 International Conventions

3.1.1 The Committee, when authorised, will act on behalf of National Administrations and, if requested, LR will certify compliance in respect of National and International Statutory Safety and other requirements for offshore units.

3.1.2 In satisfying the Load Line Conventions, the general structural strength of the unit is required to be sufficient for the draught corresponding to the freeboards to be assigned. Units built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Conventions.

3.2 International Association of Classification Societies (IACS)

3.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

3.3 International Maritime Organization (IMO)

3.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules and Regulations.

Section 4
Information required

4.1 General

4.1.1 In general, the plans and information required to be submitted are given in *Pt 4, Ch 1, 4.2 Plans and supporting information*.

4.1.2 Requirements for additional plans and information for functional unit types are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

4.1.3 Plans are generally to be submitted in triplicate, but only one copy of supporting documents and calculations will be required.

4.2 Plans and supporting information

4.2.1 Plans covering the following items are to be submitted for approval, as relevant to the type of unit:

- Bilge keel details.
- Bracings and associated primary structure.
- Corrosion control scheme.
- Deck structures including pillars and girders.
- Double bottom construction.
- Engine room construction.
- Equipment and supports.
- Erection sequence.
- Footings, pads or mats.
- Fore and aft end construction.
- Helideck.
- Ice strengthening.
- Leg structures and spuds.
- Loading manuals, preliminary and final.
- Machinery seatings.
- Main hull or pontoon structure.
- Masts and derrick posts.
- Materials and grades.
- Midship sections showing longitudinal and transverse material.
- Penetrations and attachments to primary structure.
- Profile and decks.
- Quality control and non-destructive testing procedures.
- Riser support structures.
- Rudder, stock, tiller and steering nozzles.
- Shell expansion.
- Stability columns.
- Stern frame and propeller brackets.
- Structural categories.
- Structural bulkheads and flats.
- Structure in way of jacking or elevating arrangements.
- Superstructures and deckhouses.
- Support structures for cranes, masts, derricks, flare towers and heavy equipment.
- Tank boundaries and overflows.
- Tank testing procedures and schedules.
- Temporary anchoring equipment.

- Towing arrangements and equipment.
- Transverse and longitudinal sections showing scantlings.
- Watertight sub-division.
- Watertight and oiltight bulkheads and flats.
- Watertight and weathertight doors and hatch covers.
- Welding details and procedures.

4.2.2 The following supporting plans and documents are to be submitted:

- General arrangements showing decks, profile and sections indicating all major items of equipment and machinery.
- Calculation of equipment number.
- Capacity plan.
- Cross curves of stability.
- Cross curves of allowable V.C.G.
- Design deck loading plan.
- Dry-docking plan.
- Operations Manual, *see Pt 3, Ch 1, 3 Operations manual*.
- Tank sounding tables.
- Wind heeling moment curves.
- Lines plan or equivalent.
- General arrangement showing moorings for tandem and side by side offloading. This is to include the maximum and minimum dimensions and main particulars for the range of shuttle tankers that are permitted to attend.

4.3 Calculations and data

4.3.1 The following calculations and information are to be submitted where relevant to the unit type and its design:

- Proposed class notations, operating areas and modes of operation, list of operating conditions stating proposed draughts.
- Design environmental criteria applicable to each mode, including wind speed, wave height and period, or sea state/wave energy spectra (as appropriate), water depth, tide and surge, current speed, minimum air temperature, ice and snow loads, sea bed conditions.
- A summary of weights and centres of gravity of lightship items.
- A summary of all items of deadweight, deck stores/ supplies, fuel, fresh water, drill water, bulk and sack storage, crew and effects, deck loads (actual, not design allowables), riser, guideline, mooring tensions, hook or derrick loads and ballast schedules. The summary should be given for each operating condition.
- Details of distributed and concentrated gravity and live design loadings including crane overturning moments.
- Tank content data, and design pressure heads.
- Details of tank tests, model tests, etc.
- Strength and fatigue calculations.
- Calculation of hull girder still water bending moment and shear force as applicable.
- Calculation of hull girder section modulus at midships and elsewhere as required by LR. Additional calculations to verify longitudinal strength may be required when:

(i) The maximum hogging and sagging combined still water and vertical wave bending moments do not occur at midship.
(ii) The structural arrangement at midship changes to a different arrangement within the 0,4*L* midship region.

- Stability calculations for intact and damaged cases covering a range of draughts to include all loading conditions.
- Documentation of damage cases, watertight subdivision and limits for downflooding.
- Freeboard calculation.

4.4 Specifications

4.4.1 Adequate design specifications in appropriate detail are to be submitted for information.

4.4.2 Specifications for the design and construction of the hull and structure are to include materials, grades/standards, welding construction procedures and fabrication tolerances.

4.4.3 Specifications related to the unit's proposed operations are to include environmental criteria, modes of operation and a schedule of all model tests with reports on minimum air gap, motion predictions, mooring analysis, etc. Specifications and reporting for wave basin, wind tunnel and ice tank model testing are to be in accordance with 4.6.

4.5 Plans to be supplied to the unit

4.5.1 The following plans and documents are to be placed on board the unit, *see Pt 3, Ch 1, 2 Information required*:

- Operations Manual.
- Loading Manual.
- Construction Booklet.
- Main scantlings plans.
- Corrosion control system.

4.5.2 Where an **OIWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in *Pt 3, Ch 1, 2 Information required* are also to be placed on board.

4.5.3 Where a ShipRight **CM** (Construction Monitoring) notation or descriptive note is to be assigned, the approved Construction Monitoring Plan (CMP), as detailed in the *ShipRight Construction Monitoring Procedures*, is to be maintained on board the unit.

4.6 Model test specifications and reporting

4.6.1 Model testing is to be carried out by a competent test facility which, at the discretion of LR, may require witnessing by the Surveyor. Attendance by LR would typically be limited to witnessing novel designs, novel testing techniques and at test facilities that LR is unfamiliar with. The suitability of the proposed test facility is to be discussed with LR at the earliest opportunity.

For test facilities that LR is unfamiliar with, a review of the internal quality assurance procedures of the proposed test facility may be required. The model test specification is to be submitted for review and is to be agreed with by LR before the commencement of the model tests.

4.6.2 The model is to be of an adequate scale for its intended purpose and fully representative of the features of the unit under consideration. Account is to be taken of the different draughts, trim, deck structures, topside structures and large equipment appendages as applicable (e.g. anchor racks or thrusters fairleads, turret and turntable configuration, risers) and appropriate to the type and purpose of the test.

4.6.3 Specifications for model tests are to include the following information with respect to the model, and as appropriate to the unit type and its design:

(a) Particulars and hydrostatic parameters including displacement, draught, trim, centres of buoyancy and gravity.

(b) Loading conditions and draughts to be tested and method of ballasting or loading.

(c) Lines plan, body plan and general arrangement.

(d) Mooring systems and anchor points, including general arrangement, groupings and positioning, angles, material properties and details of any truncations or substitutions to be made to account for basin limitations. For deep water moorings, the scale and any truncation technique used in the model of the positional mooring system (and risers where their damping contribution may be significant) will be subject to special consideration. Procedures for static load-displacement tests and stiffness simulation to ensure correct modelling of the mooring systems are also to be specified.

(e) Station keeping model tests are to represent the positional mooring system main characteristics as closely as practicable taking into consideration:

   (i) Mooring line components stiffness (linear or non-linear);
   (ii) Mass and inertia properties;
   (iii) Drag and added mass; and
   (iv) Interaction with sea-bed.

(f) Chosen scaling method including the relationships between the parameters to be used and any assumptions made as a result of scaling limitations. In addition, comparisons between full scale and model Reynolds and Froude numbers and drag coefficients are to be provided for the applicable environmental conditions.

(g) A description of the sign convention to be used.

(h) A list of tolerances to be used for the model testing pertaining to the model, facility and simulated environmental conditions. Modelling tolerances are to be in accordance with ITTC Recommended Procedures.

(i) Required materials and properties, types and colours of coatings to be used and details of all markings and lines to be applied. All components of the model must be coated in a colour to ensure high visibility on photographs and video and markings are to include section lines and draft marks at forward, aft and midship. Positions of any turbulence stimulators must also be clearly marked.

(j) A summary of the construction of all components of the model, including equipment, working and finishing methods to be used.

(k) For ship units fitted with an internal turret, the model specification for the turret is to include the general arrangement, turret dimensions and the method for assessing trapped water loads and motions inside the moonpool.

(l) For tension-leg units, the model specification for the tendon system is to include a detailed description of the required physical and force characteristics and material properties of the tendons.

(m) For units fitted with risers, the properties of the risers in the model test are to be specified including their position, configuration, masses, drag coefficients and axial and bending stiffness. A description of all riser configurations to be tested is also to be included.

(n) Topside configuration including general arrangement. For wave basin testing, where parts of the topsides are submerged in accidental conditions and/or extreme sea states, the modelled topsides must be of sufficient detail to provide correctly reproduced hydrostatics for the model.

(o) Where wind tunnel testing is to be performed, an above-waterline model of the unit at loaded and ballast draughts is to be used, constructed to a suitable scale to avoid a blockage ratio of greater than five per cent. Topsides are to be modelled in as much detail as practicable by manufacturing limits to accurately simulate the wind profile over the topsides of the full scale.

(p) For units fitted with thrusters, the specification for modelling the thrusters is to include the required thrust force and heading control. Any simplification of the thruster system is to be in such a way as to not affect the required forces and moments on the unit.

4.6.4 Specifications are also to include the following information relating to the test procedures, as appropriate to the unit type and extent of required testing:

(a) Specifications of the appropriate signals and response data to be recorded during the tests, including recording methods and positions of any relevant instrumentation on the model. The data is to be sufficient so that a conclusive comparison between the model tests and the corresponding simulation results can be performed. The sample rate is to be at least ten times the highest response frequency that needs to be observed. An appropriate anti-aliasing filter should be used.

(b) Specifications for calibration of the following items as applicable to the unit:

  (i) All necessary instrumentation, sensors and equipment. Accuracies must be verified in accordance with manufacturers' guidelines.
  (ii) Model particulars, including dimensions, masses and load distributions.
  (iii) Restoring forces from mooring lines and risers.
  (iv) Natural periods of the unit.
  (v) Simulated environmental conditions.

(c) Motion and acceleration tests of the unit are to be in six degrees of freedom about the centre of gravity in both regular and irregular wave conditions and are to include details of the chosen axis reference points on the model and methods for deriving motions at the centre of gravity from the recorded data. The same reference points are to be used for the model tests and post-processing of the results to facilitate comparison. Where it is not possible to measure directly at the centre of gravity e.g. when the centre of gravity lies outside the physical volume of the unit, the method to determine the motions and accelerations at the centre of gravity is to be documented.

  Turret forces, mooring line and riser tensions are also to be recorded where fitted.

(d) Wave basin tests are to be of sufficient duration to establish the low frequency behaviour and most probable maxima with sufficient reliability whilst providing also sufficient time to allow start up transient phenomena (associated with either the floating unit or the wave basin) to die down to acceptable levels.

(e) Wave basin station keeping model tests records are to focus on establishing the main characteristics of responses (e.g. mooring line tensions, offset of the offshore unit and turret loads when applicable) such as:

  (i) Mean of response;
  (ii) Standard deviation and distribution of peak values of wave frequency response; and
  (iii) Standard deviation and distribution of peak values of low frequency response.

  Most probable maximum values of response should also be estimated

(f) For tests where force sensors are under continuous tension (e.g. mooring tests) and that tension is of importance to model response (e.g. pre-tension in mooring lines influences natural periods) this pre-tension level should be measured and documented at regular intervals throughout the test campaign. As a minimum this should be done once a day.

(g) Where air gap testing is required, the specification is to include details of the location of air gap measuring points and the range of wave heights to be tested. This is to be representative of the expected site conditions. A typical number of measuring points for air gap tests for a semi-submersible is nine, spaced evenly across the model.

(h) Water elevation testing for internal turrets is to include measurements at a sufficient number of locations to determine the variation in water elevation profile, typically at a minimum of three different locations. Relative wave elevations are also to be provided external to the unit on both the port and starboard sides adjacent to the turret axis.

(i) Evidence that the effects of wave reflection and critical resonance of the natural frequencies of the wave basin and the modelled mooring system have been considered and mitigated for.

(j) Wave heights during wave generation are to be measured separately at the intended location of the unit before the test in order to provide correct reference heights for the motion test analysis. Wind and current speeds should also be measured during calibration of environments before the test.

(k) Inclination tests to verify values of metacentric height, GM (roll for mono hulls and roll and pitch for column-stabilised units) are to be carried out at the start of the model test programme. Each inclination test is to include at least three data points, preferably five, with the assessment of GM-value to be done by regression on these data points.

(l) Decay tests are to be performed for all degrees of motion and for the loading conditions specified in *Pt 4, Ch 1, 4.6 Model test specifications and reporting 4.6.3*. The amplitudes tested for damping are to be representative of the expected motions for the on-site conditions. The expected results are to include relative critical damping percentages and natural periods for all amplitudes tested in addition to mooring line and riser tensions, where fitted.

(m) Where towing tests are to be carried out, they are to include measurement of the motions and accelerations of the unit in six degrees of freedom about the centre of gravity (*see also Pt 4, Ch 1, 4.6 Model test specifications and reporting 4.6.5*(c)) and relative wave elevations at a sufficient number of locations to determine the variation in water elevation profile, typically at a minimum of nine locations along the hull and three locations around the turret or moonpool, if fitted. Wave pressures are to be taken by means of sensors at typically eight locations on the model hull. Towing speeds, accelerations and line tensions are also to be recorded.

(n) Tests of green water occurrence, wave run-up and slamming are to be performed at sufficient sampling intervals such that peak loadings are captured. Load gauges to measure green water impact pressures are to be mounted at various locations on the model (e.g. bow area, accommodation, exposed decks or horizontal braces and exposed equipment). The locations are to be agreed with LR depending on the specific design. Typically at least eight load gauges to measure green water impact pressures are to be distributed evenly over the length and breadth of the hull. Typically at least eight sensors to measure the impact pressures are to be positioned on the bow, forward deck and stern of ship units.

(o) Where bathymetry is to be modelled, schematics of the surveyed sea bed contours are to be provided in the specification, in addition to a description of the bathymetry as modelled.

(p) Where ice basin tests are to be carried out, details of the modelled ice properties for each test are to be provided, including the types of ice (e.g. ridge, brash and floe), concentration and size distribution of ice pieces, thicknesses, densities and flexural strengths. The method of ice production is also to be specified. Ice basin tests are to be taken for several drift angles and velocities. Motions and accelerations of the unit in ice are to be recorded in six degrees of freedom about the centre of gravity, (*see also Pt 4, Ch 1, 4.6 Model test specifications and reporting 4.6.5*(c)). Ice-induced pressures on the unit are to be recorded using a sufficient number of sensors positioned at the bow, midship and aft to accurately record the distribution of ice pressures over the hull. A typical number for a ship unit would be eight sensors. Ice-induced forces and moments are to be measured using an appropriate load cell arrangement. Unless it can be demonstrated that there is no interference between the measurement of ice-induced pressures and ice-induced forces and moments, these are to be measured in tests independent of each other.

(q) Wind tunnel tests are to be carried out using a model built to the specification provided in *Pt 4, Ch 1, 4.6 Model test specifications and reporting 4.6.3*. The wind tunnel is to be set up using appropriate equipment to correctly simulate the required wind profile and boundary layer as appropriate to the on-site conditions. Wind forces and moments are to be measured for 0-360 degrees in increments no greater than 10 degrees.

(r) A schedule of all tests to be performed and details of the corresponding results and deliverables are to be provided as part of the specification.

4.6.5 The model test reports are to demonstrate that the specification has been complied with, through submission of the following information:

(a) A report documenting the procedures that have been followed for both set-up and carrying out the tests.

(b) A summary of the model manufacture and set-up, including as-built drawings, materials and construction methods.

(c) Calibration test reports and results.
(d) Test results corresponding to the specification schedule.
(e) Commentary on the test results, including any comparisons with numerical simulation results. Any comparisons are to be accompanied by the corresponding numerical data.
(f) Colour photographic evidence supporting the report including the following:
  (i) Construction of all manufactured components involved in the model testing.
  (ii) Instrumentation and measurement device positions on the model.
  (iii) Basin set-up, bathymetry and positions of tank instrumentation.
  (iv) Environmental set-ups without model, e.g. wave generation.
  (v) Calibration test set-up.
  (vi) Set-up for each test.
(g) Video recordings of all tests performed, clearly showing environmental conditions and model performance, to be accompanied by video stills taken at appropriate intervals throughout the test. A video log describing the date, time and identification of the test shown is also to be provided.
(h) A chronologic test log describing for each test:
  (i) Date.
  (ii) Time.
  (iii) Test set-up.
  (iv) Environmental conditions.
  (v) Model heading.
  (vi) Remarks / observations.

■ *Section 5* Definitions

5.1 General

5.1.1 **Rule length, *L*,** in metres, for self-elevating units and semi-submersible units with twin lower hulls is to be taken as 97 per cent of the extreme length on the maximum design transit waterline measured on the centreline or on a projection of the centreline, *see Pt 4, Ch 1, 5.1 General 5.1.1*.

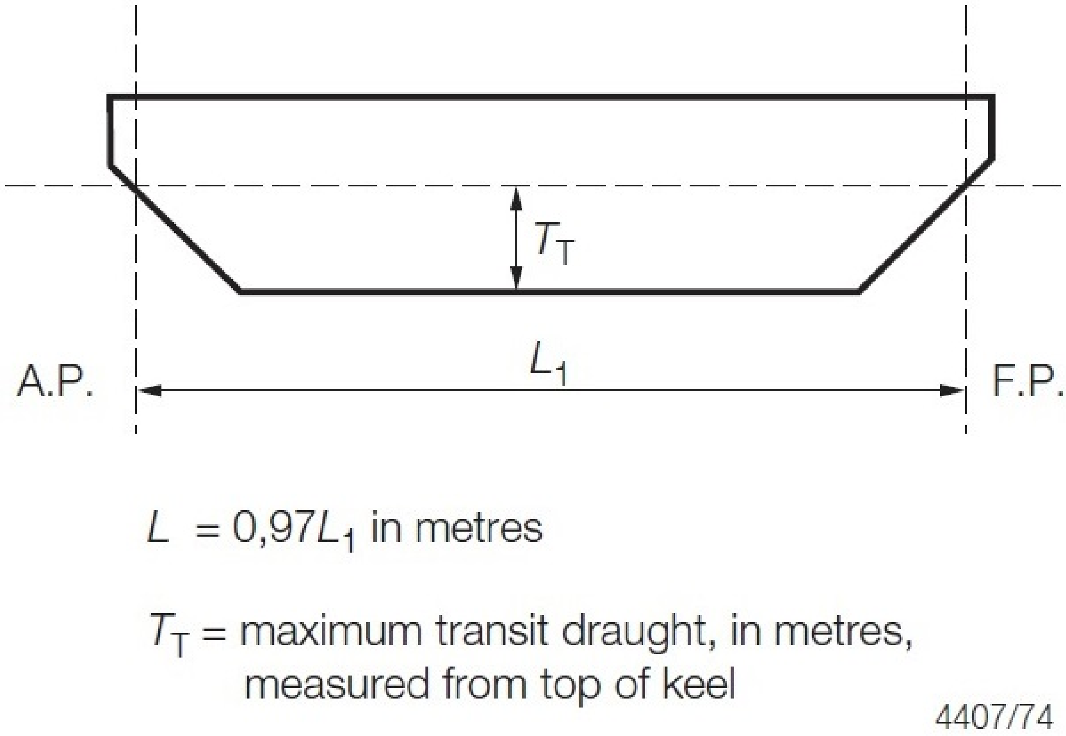


Figure 1.5.1 Rule length for self-elevating units and semi-submersible units with twin lower hulls

5.1.2 **The Rule length, *L*,** for ship units and other surface type units is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. *L* is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In ships with unusual stem or stern arrangements the Rule length, *L*, will be specially considered.

5.1.3 The Rule length for units with unconventional form will be specially considered in relation to the transit or operating waterlines.

5.1.4 **Breadth, *B*,** is the greatest moulded breadth, in metres.

5.1.5 **Depth, *D*,** is measured, in metres, at the middle of the length, *L*, from the top of keel to top of the deck beam at side on the uppermost continuous deck.

5.1.6 **Draught,** T_0 , is the maximum design operating summer draught, in metres, measured from top of keel.

5.1.7 **Draught,** T_{T} , is the maximum design transit summer draught, in metres, measured from top of keel.

5.1.8 The **block coefficient**, C_{b} , is the moulded block coefficient corresponding to the maximum design draught *T* based on the Rule length *L* and moulded breadth *B* as follows:

$$C_{\mathrm{b}} = \frac{\text{Moulded displacement } \left(\mathrm{m}^3\right) \text{ at draught T}}{LBT}$$

where

T = T_0 for ship units and other surface type units

T = T_T for self-elevating and semi-submersible units.

5.1.9 In general, the forward perpendicular, F.P., is the perpendicular at the intersection of the waterline at the draught *T* with the fore end of the hull. The aft perpendicular, A.P., is the perpendicular at the intersection of the waterline at the draught *T* with the aft end of the hull, *see also Pt 4, Ch 1, 5.1 General 5.1.2*.

5.1.10 Amidships is to be taken as the middle of the Rule length, *L*, measured from the forward side of the stem or hull.

5.1.11 **Lightweight** is defined as the weight of the complete unit with all its permanently installed machinery, equipment and outfit, including permanent ballast, spare parts normally retained on board, and liquids in machinery and piping to their normal working levels, but does not include liquids in storage or reserve supply tanks, items of consumable or variable loads, stores or crew and their effects.

■ *Section 6*
Inspection, workmanship and testing

6.1 General

6.1.1 Requirements regarding inspection, workmanship and testing are given in *Pt 4, Ch 3, 6 Procedures for testing tanks and tight boundaries* and *Ch 13, 2 Specific requirements for ship hull structure and machinery* of the Rules for Materials and should be complied with. For ship units, testing load heights are to be in accordance with *Pt 10, Ch 2, 2.3 Local static loads*.

Section 1
Materials of construction

1.1 General

1.1.1 The Rules relate in general to the construction of steel units, although consideration will be given to the use of other materials. For the use of aluminium alloys, *see Pt 4, Ch 2, 1.3 Aluminium*.

1.1.2 The materials used in the construction of the unit are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary, *see also Pt 3, Ch 1, 4 Materials*.

1.1.3 The requirements for materials for use in liquefied gas containment systems are specified in *Pt 11 PRODUCTION, STORAGE AND OFFLOADING OF LIQUEFIED GASES IN BULK* of these Rules.

1.1.4 For concrete structures, *see Pt 9, Ch 4 Materials and Durability*.

1.2 Steel

1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 When higher tensile steel is used in the construction of the unit the local scantlings determined from the Rules for steel plating, longitudinals, stiffeners and girders, etc., may be based on a *k* factor determined as follows:

$$k = \frac{235}{\sigma_o}\left(k = \frac{24}{\sigma_o}\right)$$

or 0,66, whichever is the greater

where

σ_o = specified minimum yield stress, of the higher tensile steel in N/mm^2 (kgf/mm^2).

1.2.3 When higher tensile steel is used in the primary structure of ship units, the determination of the hull girder section modulus is to be based on a higher tensile steel factor k_L kL determined in accordance with *Pt 4, Ch 2, 1.2 Steel 1.2.3*.

Table 2.1.1 Values of

Specified minimum yield stress In N/mm^2 (kgf/mm^2)	k_L
235 (24)	1,0
265 (27)	0,92
315 (32)	0,78
355 (36)	0,72

390 (40)	0,66
460 (47)	0,62
NOTES	
1. Intermediate values by linear interpolation.	
2. For the purpose of calculating hull moment of inertia as specified in *Pt 3, Ch 4, 5.8 Hull moment of inertia 5.8.1* of the Rules for Ships, k_{L} =1,0.	

1.2.4 For the application of the requirements of *Pt 4, Ch 2, 1.2 Steel 1.2.2* and *Pt 4, Ch 2, 1.2 Steel 1.2.3*, special consideration will be given to steel where σ_{o} > 355 N/mm^2 (36 kgf/mm^2). Where such steel grades are used in areas which are subject to fatigue loading, the structural details are to be verified using fatigue design assessment methods.

1.2.5 Where steel castings or forgings are used for major structural components, they are to comply with *Ch 4 Steel Castings* or *Ch 5 Steel Forgings* of the Rules for Materials, as appropriate.

1.3 Aluminium

1.3.1 The use of aluminium alloy is permitted for superstructures, deckhouses, hatch covers, helicopter platforms, or other local components on board offshore units, except where stated otherwise in *Pt 3, Ch 1, 4.5 Aluminium structure, fittings and paint*.

1.3.2 Except where otherwise stated, equivalent scantlings are to be derived as follows:

Plating thickness:

$$t_{\text{a}} = t_{\text{s}}\sqrt{k_{\text{a}}c}$$

Section modulus of stiffeners:

$$Z_{\text{a}} = Z_{\text{s}}k_{\text{a}}c$$

where

c = 0,95 for high corrosion resistant alloy
= 1,0 for other alloys

$$k_{\text{a}} = \frac{235}{\sigma_{\text{o}}}$$

t_{a} = thickness of aluminium plating

t_{s} = thickness of mild steel plating

Z_{a} = section modulus of aluminium stiffener

Z_{s} = section modulus of mild steel stiffener

σ_{a} = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

1.3.3 In general, for welded structure, the maximum value of σ_{a} to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location, or other heat affected zones, in relation to the maximum applied stress on the member (e.g., extruded sections).

1.3.4 A comparison of the mechanical properties for selected welded and unwelded alloys is given in *Pt 4, Ch 2, 1.3 Aluminium 1.3.6*.

1.3.5 Where strain hardened grades (designated Hxxx) are used, adequate protection by coating is to be provided to avoid the risk of stress corrosion cracking.

1.3.6 The use of aluminium alloy for primary structure will be specially considered.

Table 2.1.2 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm²		Ultimate tensile strength, N/mm²	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (*see* Note 1)	T5/T6	Extruded: Open Profile	215	100	260	160
		Extruded: Closed Profile	215	100	250	160
6061 (*see* Note 1)	T5/T6	Rolled	240	125	290	160
		Extruded: Open Profile	240	125	260	160
		Extruded: Closed Profile	205	125	245	160
6082	T5/T6	Rolled	240	125	280	190
		Extruded: Open Profile	260	125	310	190
		Extruded: Closed Profile	240	125	290	190

NOTES

1. These alloys are not normally acceptable for application in direct contact with sea-water.

2. *See also Ch 8, 1.5 Chemical composition 1.5.2* or *Ch 8, 1.8 Mechanical tests 1.8.3* of the Rules for Materials.

3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also Ch 8, 1.1 Scope 1.1.5* of the Rules for Materials.

4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat affected zones and weld lines, *see also Pt 4, Ch 2, 1.3 Aluminium 1.3.3*.

5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm² and the minimum tensile strength is to be taken as 315 N/mm².

■ Section 2
Structural categories

2.1 General

2.1.1 For the determination of steel grades in accordance with *Pt 4, Ch 2, 4.1 General*, all structural components of the unit may be grouped into structural categories taking into account the following aspects:

(a) Applied loading, stress level and the associated stress pattern.
(b) Critical load transfer points and stress concentrations.
(c) Consequence of failure.

2.1.2 The structural categories can be summarised as follows:

(a) **Special structure:**

Primary structural elements which are in way of critical load transfer points and stress concentrations.

(b) **Primary structure:**

Structural elements essential to the overall integrity of the unit.

(c) **Secondary structure:**

Structural elements of less importance than primary structure, failure of which would be unlikely to affect the overall integrity of the unit.

2.1.3 For the structural categories of supporting structures of drilling plant and production and process plant, *see Pt 3, Ch 7, 2.2 Materials* and *Pt 3, Ch 8, 2.2 Materials* respectively.

2.2 Column-stabilised and tension-leg units

2.2.1 In general, the structural members of column-stabilised and tension-leg units are to be grouped into the following structural categories:

(a) **Special structure:**

(i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or '**I**' type supporting structure in way of critical load transfer points and which receive major concentrated loads.
(ii) The shell plating in way of the intersections of vertical columns with platform decks and upper and lower hulls.
(iii) End connections and major intersections of primary bracing members.
(iv) Critical load transfer by 'through' material used at connections of vertical columns, upper platform decks and upper or lower hulls which are designed to provide proper alignment and adequate load transfer.
(v) External brackets, portions of bulkheads, flats, and frames which are designed to receive concentrated loads at intersections of major structural members.
(vi) Structure supporting concentrated mooring loads.
(vii) Deck cantilevers
(viii) Towing brackets

(b) **Primary structure:**

(i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or '**I**' type supporting structure except where the structure is considered as special application.
(ii) The shell plating of vertical columns, lower and upper hulls, and diagonal and horizontal braces.
(iii) Bulkheads, flats or decks, stiffeners and girders which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered as special application.
(iv) Main support structure to cantilevered helicopter decks and lifeboat platforms.
(v) Heavy substructures and equipment supports, e.g., drillfloor substructure, crane pedestals, anchor line fairleads and their supporting structure, *see also Pt 4, Ch 2, 2.1 General 2.1.3*
(vi) Riser support structure.

(c) **Secondary structure**:

- (i) Upper platform decks or decks of upper hulls, except areas where the structure is considered as primary or special application.
- (ii) Bulkheads, stiffeners, flats, decks, girders and web frames in vertical columns, upper and lower hulls, diagonal and horizontal bracing, which are not considered as primary or special application.
- (iii) Helicopter platforms and deckhouses.
- (iv) Lifeboat platforms, walkways, guard rails and minor fittings and attachments, etc.

2.3 Self-elevating units

2.3.1 In general, the structural members of self-elevating units are to be grouped into the following categories:

(a) **Special structure:**

- (i) Vertical columns in way of intersections with the mat structure.
- (ii) Intersections of lattice type leg structures which incorporate novel construction, including the use of steel castings.
- (iii) Leg to spudcan connections.
- (iv) Jack-house and/or bulkheads supporting locking.

(b) **Primary structure:**

- (i) The plating of bulkheads, decks and shell boundaries of the main hull or platform which in combination form 'box' or '**I**' type main supporting structure.
- (ii) External plating of cylindrical legs.
- (iii) Plating of all components of lattice type legs.
- (iv) Jack-house supporting structure.
- (v) External shell plating of footings and mats and structural components which receive initial transfer of loads from the leg structures.
- (vi) Internal bulkheads and girders of supporting structure of footings and mats which are designed to distribute major concentrated or uniform loads into the structure.
- (vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
- (viii) Heavy substructures and equipment supports, e.g., drillfloor substructure, drilling cantilevers, supports for raw water towers and crane pedestals, *see also Pt 4, Ch 2, 2.1 General 2.1.3*.
- (ix) Towing brackets.

(c) **Secondary structure:**

- (i) Deck and shell boundaries of the main hull or platform, except where the structure is considered as primary application.
- (ii) Internal bulkheads, decks stiffeners and girders of the main hull structure, except where the structure is considered as primary structure.
- (iii) Internal diaphragms, girders or stiffeners in cylindrical legs.
- (iv) Internal bulkheads, stiffeners and girders of footings and bottom mat supporting structures, except where the structure is considered primary or special application.
- (v) Helicopter platforms and deckhouses.
- (vi) Lifeboat platforms and walkways.

2.4 Ship units and other surface type units

2.4.1 Material classes and steel grades for individual areas of the hull structure of ship and barge type units are to comply with*Pt 3, Ch 2, 2 Fracture control* of the Rules for Ships.

2.4.2 Where the minimum design temperature, *see Pt 4, Ch 2, 3.1 General*, for exposed structure is –5°C or below, or for structural components not addressed by *Pt 4, Ch 2, 2.4 Ship units and other surface type units 2.4.1*, the requirement of *Pt 4, Ch 2, 2.4 Ship units and other surface type units 2.4.3* should be complied with and the steel grades should be assigned in accordance with *Pt 4, Ch 2, 4.1 General 4.1.6*.

2.4.3 In general, the structure of ship units and other surfaces type units is to be grouped into the following structural categories:

(a) **Special structure:**

(i) Structure in way of critical load transfer points which are designed to receive major concentrated loads in way of mooring systems, including yokes and similar structures, and supports to hawsers to mooring installations including external hinges, complex padeyes, brackets and supporting structures.
(ii) Sheerstrake or rounded gunwale.
(iii) Stringer plate at strength deck.
(iv) Deck strake at longitudinal bulkheads.
(v) Bilge strake.
(vi) Continuous longitudinal hatch coamings.

(b) **Primary structure:**

(i) Strength deck and raised quarter deck plating except where categorised '**special**'.
(ii) Bottom shell plating of the main hull except where categorised '**special**'.
(iii) Bulkhead plating in way of moonpools, drilling wells and circumturret.
(iv) Upper strake in longitudinal bulkheads.
(v) Continuous longitudinal members above strength deck except where categorised '**special**'.
(vi) Vertical strake (hatch side girder) and upper sloped strake in top wing tanks.
(vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
(viii) Heavy substructures and equipment supports, e.g. integrated support stools to process plant, drill floor substructure, crane pedestals, anchor line fairleads and chain stoppers for positional mooring systems and their supporting structures, *see also Pt 4, Ch 2, 2.1 General 2.1.3*.
(ix) Riser support structures.
(x) Turret bearing support structure.
(xi) Swivel stack support structure.
(xii) Supporting structures to external turret.
(xiii) Deck cantilevers
(xiv) Towing brackets

(c) **Secondary structure:**

(i) Bulkhead plating, side shell, longitudinals, stiffeners, deck plating including poop deck and forecastle deck, flats, girders and web frames, etc., except where the structure is categorised as **special** or **primary** structure. For topside plant supporting structures, *see also Pt 4, Ch 2, 2.1 General 2.1.3*
(ii) Helicopter platforms and deckhouses.
(iii) Lifeboat platforms, walkways, guard rails, minor fittings and attachments, etc.

2.5 Buoys, deep draught caissons, turrets and miscellaneous structures

2.5.1 In general, the structure of buoys, deep draught caissons, turrets, and other miscellaneous structures included in *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures* is to be grouped into the following structural categories:

(a) **Special structure:**

(i) Structure in way of critical load transfer points which are designed to receive major concentrated loads including external brackets, portions of bulkheads, flats and frames.
(ii) Intersections of structures which incorporate novel construction including the use of steel castings.
(iii) Complex padeyes.
(iv) Highly stressed structural elements of anchor-line attachments.
(v) Bearings and structure at the base of mooring towers.

(b) **Primary structure**: The following structural members are categorised as primary, except when the structure is considered as special application:

(i) External shell plating of buoys, deep draught caissons, turrets and subsea modules.
(ii) Strength decks of buoys and deep draught caissons.
(iii) Truss structure supporting decks on deep draught caissons.
(iv) Miscellaneous structures:

- Support stools to process plant.
- Bearing support structure.

- Mating cone structure for turret buoys.
- Swivel stack support structure.
- Turntable construction.
- Chain tables.
- Riser support structure.
- Hawser support structure.
- Yoke and mooring arm construction.
- Mooring towers.

(v) Main support structures to cantilevered helideck and lifeboat platforms.

(vi) Heavy substructures and equipment supports, e.g., crane pedestals, anchor line fairleads for positional moorings, chain stoppers and their supporting structures.

(vii) Boundary bulkheads of moonpools.

(viii) Towing brackets

(c) **Secondary structure:**

(i) Bulkheads, stiffeners, decks, flats, etc., except where the structure is categorised as Special or Primary structure. For topside structures, *see also Pt 4, Ch 2, 2.1 General 2.1.3*.

(ii) Helicopter platforms and deckhouses.

(iii) Lifeboat platforms, walkways, guard rails and minor fittings and attachments, etc.

■ *Section 3*
Design temperature

3.1 General

3.1.1 The Minimum Design Temperature (MDT) is a reference temperature used as a criterion for the selection of the grade of steel to be used in the structure and is to be determined in accordance with *Pt 3, Ch 1, 4 Materials*.

3.1.2 The MDT is not to exceed the lowest service temperature of the steel as appropriate to the position in the structure.

3.1.3 A design temperature of 0°C is generally acceptable for determining the steel grades for structure which is normally underwater, *see also Pt 4, Ch 2, 4.1 General 4.1.4*.

3.1.4 For column-stabilised units of conventional design, the lower hulls need not normally be designed for a design temperature lower than 0°C.

3.1.5 The design temperature for internal structure of all units is to be separately defined, *see* Lloyd’s Register's *Provisional Rules for the Winterisation of Ships*.

3.1.6 Internal structures in way of permanently heated compartments need not normally be designed for temperatures lower than 0°C.

■ *Section 4*
Steel grades

4.1 General

4.1.1 The grades of steel to be used in the structure are, in general, related to the thickness of the material, the structural category and the MDT. The grades of steel to be used in the construction of the unit are to be determined from *Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction*, *see also Pt 4, Ch 2, 4.1 General 4.1.5* and *Pt 4, Ch 2, 2 Structural categories*. Material thicknesses greater than those shown in *Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction* may be specially considered by LR, e.g., legs of self-elevating units.

4.1.2 Special consideration will be given to the use of higher tensile steel grades with a minimum yield stress greater than 390 N/mm^2, e.g., legs of self-elevating units.

4.1.3 For materials where the principal loads or welding stresses are perpendicular to the plate thickness, the requirements for through thickness properties must be considered. The specific requirements for through thickness testing and/or for low sulphur level should be determined using either EN 1993-1-10 or, subject to the agreement of Lloyd’s Register, an alternative recognised national or international standard.

In addition to the above, special consideration shall be given to the requirements for through-thickness testing for critical joints with a restricted load path, for example, mooring fairlead attachments and anchor line or hawser connections.

4.1.4 Steel grades for units required to operate in severe ice conditions will be specially considered. Temperature gradient calculations may be required to assess the design temperature of the structure, *see also Pt 3, Ch 6 Units for Transit and Operation in Ice*.

4.1.5 Minor structural components such as guard rails, walkways and ladders, etc., are, in general, to be constructed of Grade A steel, unless agreed otherwise by LR, *see also Pt 4, Ch 2, 4.1 General 4.1.4*.

4.1.6 For components listed in *Table 2.4.2 Application where fracture mechanics may be considered to permit alternative grades of steel*, special consideration may be given to material grades with other impact properties than those required by *Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction*. In such cases, written agreement is required prior to manufacture. This evaluation is to be based on critical engineering assessment involving fracture mechanics testing on welded material from the intended supplier and proposals are to be submitted which include full details of the application, minimum temperature, design, design stresses, fatigue loads and cycles, welding procedures that will be applied and inspection procedures.

Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction

Structural category	Required steel grade	Maximum thickness permitted (mm) for various minimum design temperatures, *see* Note 8			
		0°C	–10°C	–20°C	–30°C
Secondary	A	30	20	12,5	X
	B	60	50	25	10
	D	100	100	80	50
	E	150	150	120	100
	AH	50	40	25	10
	DH	100	100	70	50
	EH	150	150	100	80
	FH	150	150	150	120
	AQ	50	40	25	10
	DQ	100	100	70	50
	EQ	150	150	120	80
	FQ	150	150	150	120

Primary	A	20	12,5	X	X
	B	25	25	12,5	X
	D	50	50	30	20
	E	100	100	65	40
	AH	25	25	12,5	X
	DH	50	50	30	20
	EH	120	100	65	40
	FH	150	150	150	100
	AQ	25	25	X	X
	DQ	50	50	30	20
	EQ	120	100	65	40
	FQ	150	150	150	100
Special	A	12,5	X	X	X
	B	15	12,5	X	X
	D	30	30	20	10
	E	100	75	35	30
	AH	20	12,5	X	X
	DH	30	30	12,5	10
	EH	100	75	35	25
	FH	150	100	80	50
	AQ	15	12,5	X	X
	DQ	30	30	12,5	10
	EQ	100	75	30	25
	FQ	150	100	80	60

NOTES

1. X indicates that the material is not permitted for that design temperature and structural category.

2. Materials are to comply with the requirements of *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* of the Rules for Materials.

3. Q grades refer to quenched and tempered grades (*Ch 3, 10 High strength quenched and tempered steels for welded structures* of the Rules for Materials).

4. The thicknesses refer to as constructed thicknesses (e.g., design thickness plus any allowances such as corrosion allowance).

5. Requirements for minimum design temperature lower than –30°C will require special consideration which may include the use of fracture mechanics assessments.

6. Thicknesses greater than those shown in this Table may be used subject to special consideration by LR and may include fracture mechanics assessment.

7. The interpolation of thicknesses for intermediate temperatures may be considered.

8. For LNG installations where the minimum hull shell plating temperature used in the design is the result of heat conduction from the cargo rather than environmental conditions, the material thicknesses shall be in accordance with *Pt 11, Ch 6, 1.4 Requirements for metallic materials 1.4.1* in *Pt 11, Ch 6 Materials of Construction and Quality Control* .

Table 2.4.2 Application where fracture mechanics may be considered to permit alternative grades of steel

Application
Lattice type leg structures
Cylindrical legs
Footing and mats

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter indicates the general design concepts and loading and the general principles adopted in applying the Rule structural requirements given in this Part.

1.1.2 General definitions of span point, derivation of geometric properties of section and associated effective area of attached plating are given in this Chapter.

1.1.3 Additional requirements relating to functional unit types are also dealt with under the relevant unit type given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

1.1.4 General principles of subdivision and requirements for cofferdams are given in this Chapter.

1.1.5 *Pt 4, Ch 3, 2 Design concepts* and *Pt 4, Ch 3, 5 Number and disposition of bulkheads* are not applicable to ship units and other surface type units. Instead, structural idealisation aspects of ship units are to comply with *Pt 10, Ch 1, 8 Structural idealisation* and *Pt 4, Ch 3, 3 Structural idealisation*, as applicable. Structural idealisation aspects of other surface type units are to comply with *Pt 3, Ch 3, 3 Structural idealisation* of the Rules for Ships.

1.1.6 The number and arrangement of bulkheads on ship units and other surface type units are given in *Pt 3, Ch 3, 4 Bulkhead requirements* of the Rules for Ships, which are to be complied with, as applicable.

1.1.7 For all unit types, structural design loads as given in *Pt 4, Ch 3, 4 Structural design loads* should be considered as applicable.

■ *Section 2*
Design concepts

2.1 Elastic method of design

2.1.1 In general, the approval of the primary structure of the unit will be based on the elastic method of design and the permissible stresses in the structure are to be based on the minimum factors of safety defined in *Pt 4, Ch 5 Primary Hull Strength* When specifically requested, LR will consider other design methods.

2.2 Limit state method of design

2.2.1 When the limit state method of design is proposed for the structure, the design methods, load combinations and partial factors are to be agreed with LR.

2.3 Plastic method of design

2.3.1 When the plastic method of design based on the ultimate strength is proposed for the structure, the load factors are to be in accordance with an acceptable Code of Practice, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

2.4 Fatigue design

2.4.1 All units are to be capable of withstanding the fatigue loading to which they are subjected. The fatigue design requirements are given in *Pt 4, Ch 5, 5 Fatigue design*.

■ *Section 3*
Structural idealisation

3.1 General

3.1.1 In general, the special and primary structure of a unit is to be analysed by a three-dimensional finite plate element method. Only if it can be demonstrated that other methods are adequate will they be considered.

3.1.2 The complexity of the mathematical model together with the associated computer element types used must be sufficiently representative of all the parts of the primary structure to enable accurate internal stress distributions to be obtained.

3.1.3 When requested, LR can perform an independent structural analysis of the unit.

3.1.4 For derivation of local scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.5 Apart from local requirement for web thickness or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

b = actual width, in metres, of the load-bearing plating, i.e., one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0,3\left(\frac{l}{b}\right)^{2/3}$ but is not to exceed 1,0. Values of this factor are given in *Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.1*

l = overall length, in metres, of the primary support member, *see Pt 4, Ch 3, 3.3 Determination of span point 3.3.4*

t_p = thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 3.3.1 Effective width factor

l	*f*	*l*	*f*
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00

NOTE

Intermediate values to be obtained by linear interpolation.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness t_{p} mm and of width 600 mm or 40 t_{p} mm, whichever is the greater. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_{p} , is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing *p* is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$Z = \frac{d_{\mathrm{w}}}{6000}\left(3b\,t_{\mathrm{p}} + c\,t_{\mathrm{w}}\right)\mathrm{cm}^3$$

where

d_{w} ,*b*, t_{p} ,*c* and t_{w} are measured, in mm, and are as shown in *Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.4*. The value of *b* is to be taken not greater than:

$50t_{\mathrm{p}}\sqrt{k}$ for welded corrugations

$60t_{\mathrm{p}}\sqrt{k}$ for cold formed corrugations

The value of θ is to be taken not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10}\left(\frac{d_{\mathrm{w}}}{2}\right)\mathrm{cm}^4$$

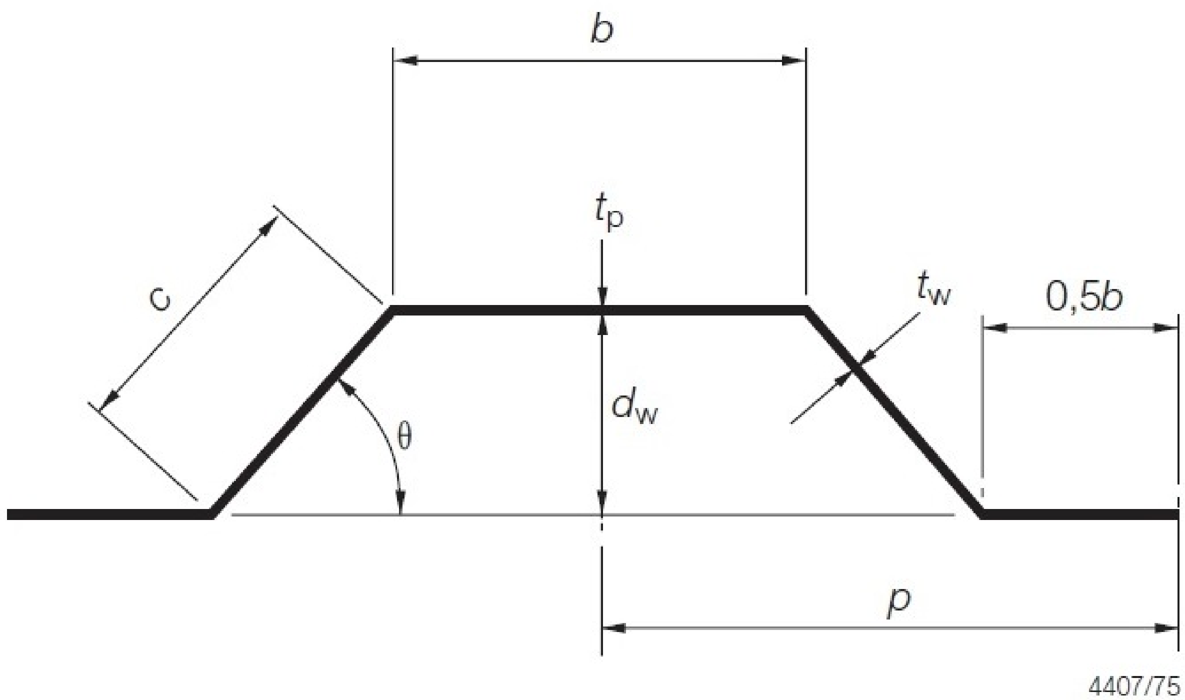


Figure 3.3.1 Corrugation geometry

3.2.5 The section modulus of a double plate bulkhead over a spacing *b* may be calculated as:

$$z = \frac{d_\text{w}}{6000}\left(6f\, b\, t_\text{p} + d_\text{w} t_\text{w}\right) \text{cm}^3$$

where

d_w ,*b*, t_p and t_w are measured, in mm, and are as shown in *Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.5*.

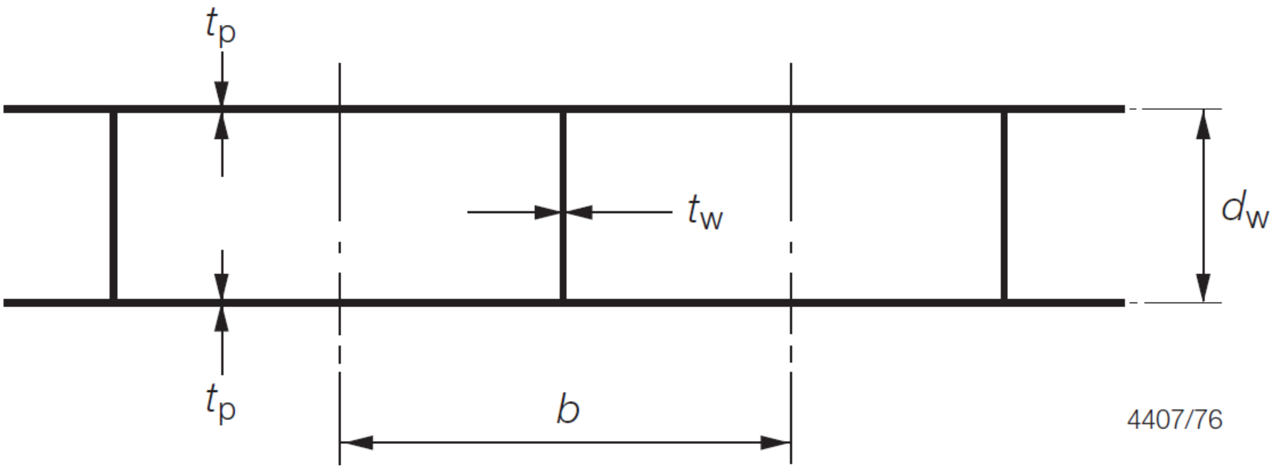


Figure 3.3.2 Double plate bulkhead geometry

3.2.6 The effective section modulus of a built section may be taken as:

$$z = \frac{a d_w}{10} + \frac{t_w d_w^2}{6000}\left(1 + \frac{200(A - a)}{200A + t_w d_w}\right) \text{cm}^3$$

where

a = area of the face plate of the member, in cm^2

d_w = depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

t_w = thickness of the web of the section, in mm

A = area, in cm$_2$, of the attached plating, *see Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.7*. If the calculated value of *A* is less than the face area *a*, then *A* is to be taken as equal to *a*.

3.2.7 The geometric properties of primary support members (i.e., girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, *A*, determined as follows:

(a) For a member attached to plane plating:

$$A = 10f\ b\ t_p \text{ cm}^2$$

(b) For a member attached to corrugated plating and parallel to the corrugations:

$$A = 10\,b\ t_p \text{ cm}^2$$

See Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.4.

(c) For a member attached to corrugated plating and at right angles to the corrugations, *A* is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective length, l_e , of a stiffening member is generally less than the overall length, **l**, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built secondary stiffening members, the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double skin construction the span may be reduced by the depth of primary member web stiffener, *see Pt 4, Ch 3, 3.3 Determination of span point 3.3.4*

(b) For primary support members: the span point is to be taken at a point distant b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

See also Pt 4, Ch 3, 3.3 Determination of span point 3.3.4.

3.3.2 Where the end connections of longitudinals are designed with brackets to achieve compliance with the *ShipRight FDA* Procedure, no reduction in span is permitted for such brackets unless the fatigue life is subsequently reassessed and shown to be adequate for the resulting reduced scantlings.

3.3.3 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

3.3.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

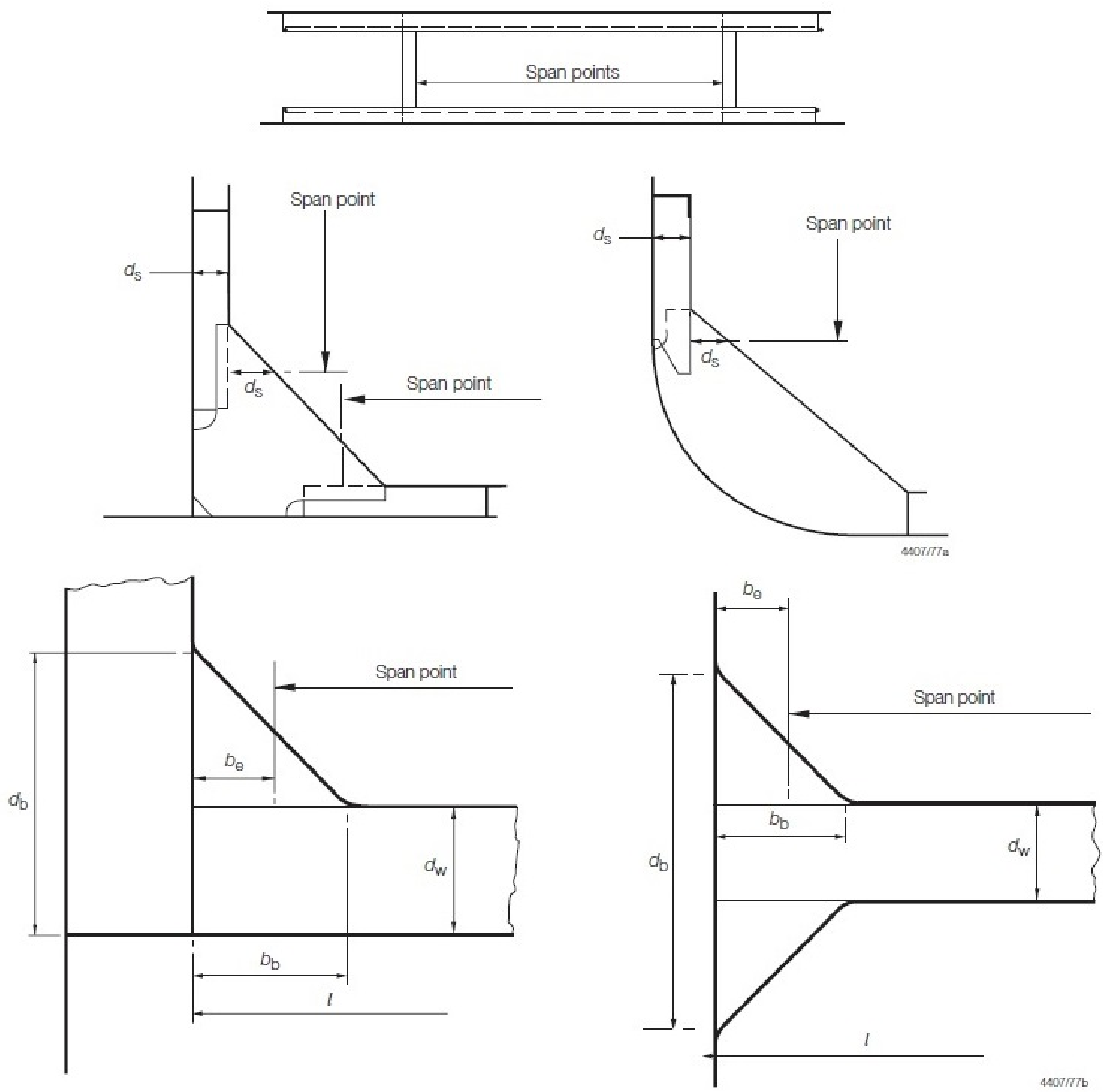


Figure 3.3.3 Span points

3.4 Grouped stiffeners

3.4.1 Where stiffeners are equally spaced and are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of:

(a) the mean value of the section modulus required for individual stiffeners within the group; and

(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

Section 4
Structural design loads

4.1 General

4.1.1 The requirements in this Section define the loads and load combinations to be considered in the overall strength analysis of the unit and the design pressure heads to be used in the Rules for local scantlings.

4.1.2 A unit's modes of operation are to be investigated using realistic loading conditions, including buoyancy, gravity and functional loadings together with relevant environmental loadings. Due account is to be taken of the effects of wind, waves, currents, motions (inertia), moorings, ice, and, where necessary, the effects of earthquake, sea bed-supporting capabilities, temperature, fouling, etc. Where applicable, the design loadings indicated herein are to be adhered to for all types of offshore units.

4.1.3 The Owner/designer is to specify the modes of operation and the environmental conditions for which the unit is to be approved, *see also Pt 1, Ch 2, 2 Definitions, character of classification and class notations*.

4.1.4 The design environmental criteria determining the loads on the unit and its individual elements are to be based upon appropriate statistical information and have a return period (period of recurrence) for the most severe anticipated environment of at least:

(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a Fixed Location.

If a unit is restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must also be specified.

4.1.5 Model tests are to be carried out as necessary and the tests are to include means of establishing the effects of green water loading and/or slamming on the structure through video recordings of the model testing and by measurement of the following:

- Relative motions.
- Forces on local panels mounted at various locations on exposed areas including bow areas of ship units and other surface type units and accommodation areas, *see also Pt 10 SHIP UNITS* for ship units and *Pt 4, Ch 4 Structural Unit Types* and *Pt 3, Ch 10, 5 Design analysis* for other unit types.

4.1.6 When carrying out model tests, account is to be taken of the following:

- The test programme and the model test facilities are to be to LR's satisfaction.
- The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined.
- The tests are to be of sufficient duration to establish low frequency motion behaviour.

4.1.7 The unit's limiting design criteria are to be included in the Operations Manual, *see Pt 3, Ch 1, 3 Operations manual*.

4.2 Definitions

4.2.1 **Still water condition** is defined as an ideal condition when no environmental loads are imposed on the structure, e.g., no wind, wave or current, etc.

4.2.2 **Gravity and functional loads** are loads which exist due to the unit's weight, use and treatment in still water conditions for each design case. All external forces which are responses to functional loads are to be regarded as functional loads, e.g., support reactions and still water buoyancy forces.

4.2.3 **Environmental loads** are loads which are due directly or indirectly to environmental actions. All external forces which are responses to environmental loads are to be regarded as environmental loads, e.g., mooring forces and inertia forces.

4.2.4 **Accidental loads** are loads which occur as a direct result of an accident or exceptional circumstances, e.g., loads due to collisions, dropped objects and explosions, etc. *See also Pt 4, Ch 3, 4.16 Accidental loads*.

4.3 Load combinations

4.3.1 The structure is to be designed for the most unfavourable of the following combined loading conditions (as relevant to the unit):

(a) Maximum gravity and functional loads.
(b) Design environmental loads and associated gravity and functional loads.
(c) Accidental loads and associated gravity and functional loads.
(d) Environmental loads and associated gravity and functional loads after credible failures or accidents, *see Pt 4, Ch 4, 1.3 Structural design 1.3.5* for redundancy assessment of column-stabilised units and *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.1* for assessment of ship units in the flooded condition.

NOTE

Pt 4, Ch 3, 4.3 Load combinations 4.3.1 relates to the loading and condition of the unit at the time of the accidental event. *Pt 4, Ch 3, 4.3 Load combinations 4.3.1* relates to the loading and condition of the unit following the accidental event and allowing for agreed documented mitigation measures to be put in place. *See also Pt 4, Ch 3, 4.16 Accidental loads*, *Pt 4, Ch 4 Structural Unit Types* and *Pt 10 SHIP UNITS* for applicability to unit types.

4.3.2 Special requirements applicable to column-stabilised and self-elevating units are also defined in *Pt 4, Ch 4 Structural Unit Types*.

4.3.3 Permissible stresses relevant to the combined loading conditions are given in *Pt 4, Ch 5 Primary Hull Strength*.

4.4 Gravity and functional loads

4.4.1 All gravity loads, including static loads such as weight, outfit, stores, machinery, ballast, etc., and live functional loads from operating derricks, cranes, winches and other equipment are to be considered. All practical combinations of gravity and functional loads are to be included in the design cases.

4.5 Buoyancy loads

4.5.1 Buoyancy loads on all underwater parts of the structure, taking account of heel and trim when appropriate, are to be considered.

4.6 Wind loads

4.6.1 Account is to be taken of the wind forces acting on that part of the unit which is above the still water level in all operating conditions and of the following:

(a) Consideration is to be given to wind gust velocities which are of brief duration and sustained wind velocities which act over intervals of time equal to or greater than one minute, including squalls where relevant. Different wind velocity averaging time intervals applicable to different structural categories to be used in design calculations are shown in *Table 3.4.1 Structural parts to be considered for wind loading*.
(b) Wind velocities are to be specified relative to a standard reference height of 10 m above still water level for each operating condition.
(c) The variation of wind velocity with height and averaging time interval for each applicable condition may be determined from the following expression:

$$V_{HT} = V_R\left(1 + C\ln\frac{H}{H_R}\right) \bullet \left(1 - 0,41 I_U \ln\frac{T}{T_0}\right)$$

where

$$C = 0,05731 + \left(0,148 V_R\right)^{0,5}$$

$$I_U = 0,06\left(1 + 0,043 V_R\right) \bullet \left(\frac{H}{H_R}\right)^{-0,22}$$

and

V_R = wind velocity at specified reference height H_R and reference time period T_0, in m/s

H = specified height above sea level, in meters

H_R = reference height, in metres

T = wind speed averaging time interval, in seconds

T_0 = reference time period, 1 hour, in seconds

Table 3.4.1 Structural parts to be considered for wind loading

Wind speed averaging time interval	Structural category
3 second gust	Individual members and equipment secured to them
5 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension does not exceed 50 m
15 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension exceeds 50 m
1 minute mean (sustained) *see* Note	The whole structure of the unit regardless of dimension for use with the maximum wave and current loads
NOTE In no case is the one minute mean value to be taken less than 25,8 m/s (50 knots). However, for unrestricted service the following wind criteria are also to be applicable for structural design considerations: (a) for all modes of operation, whether afloat or supported by the sea bed, a sustained one minute mean wind velocity of not less than 36 m/s (70 knots) (b) for the survival condition, a sustained one minute mean wind velocity of not less than 51,5 m/s (100 knots) The factors of safety are to comply with *Pt 4, Ch 5, 2.1 General 2.1.1* loadcase (b).	

4.6.2 The wind force is to be calculated for each part of the structure and is not to be taken less than:

$$F = K_{\mathrm{w}} A\ V^2\ C_{\mathrm{s}}\ \mathrm{N(kgf)}$$

where

F = net force acting on any member or part of the unit. This includes the effect of any suction on back surfaces

K_{w} = 0,613 (0,0625)

A = projected area of all exposed surfaces in upright or heeled position, in m^2

V = wind velocity, in m/s, *see Pt 4, Ch 3, 4.6 Wind loads 4.6.1*

C_{s} = shape coefficient as given in *Pt 4, Ch 3, 4.6 Wind loads 4.6.2*.

Table 3.4.2 Values of coefficient

Shape	C_{s}
Spherical	0,40
Cylindrical	0,50

Large flat surface (hull, deckhouse, smooth underdeck areas)	1,00
Drilling derrick	1,25
Wires	1,20
Exposed beams and girders under deck	1,30
Small parts	1,40
Isolated shapes (cranes, booms, etc.)	1,50
Clustered deckhouses or similar structures	1,10
NOTE Shapes or combinations of shapes which do not readily fall into the specified categories will be subject to special consideration.	

4.6.3 When calculating wind forces the following procedures should be considered:

(a) Shielding may be taken into account when a member or structure lies closely enough behind another to have a significant effect. Procedures for determining the shielding effect and loading are to be acceptable to LR.
(b) Areas exposed due to heel, such as underdecks, etc., are to be included using the appropriate shape coefficients.
(c) If several deckhouses or structural members, etc., are located close together in a plane normal to the wind direction, the solidification effect is to be taken into account. The shape coefficient may be assumed to be 1,1.
(d) Isolated houses, structural shapes, cranes, etc., are to be calculated individually, using the appropriate shape coefficient.
(e) Open truss work commonly used for derrick towers, booms and certain types of masts may be approximated by taking 30 per cent of the projected block area of each side, e.g., 60 per cent of the projected block area of one side for double-sided truss work. An appropriate shape coefficient is to be taken from *Pt 4, Ch 3, 4.6 Wind loads 4.6.2*.

4.6.4 For slender structures and components, the effects of wind-induced cross-flow vortex vibrations are to be included in the design loading.

4.6.5 For slender structures sensitive to dynamic loads, the static gust wind force is to be multiplied by an appropriate dynamic amplification factor.

4.7 Current loads

4.7.1 In storm conditions, the current has two main components: the tidal and wind driven components. Submitted information on currents is to include tidal and wind induced components and the variation of their profiles with water depth, *see Pt 4, Ch 3, 4.9 Wave loads 4.9.6* and *Pt 4, Ch 3, 4.9 Wave loads 4.9.7*. In addition, the effects of general circulation and loop currents are to be included where appropriate.

4.8 Orientation and wave direction

4.8.1 Loadings are to be assessed using sufficient wave headings and crest positions to determine the most severe loading on the unit. In addition to the design wave height and period, the unit is to be designed to withstand shorter period waves of less height when these can induce more severe loading on parts or the whole unit due to dynamic effects, etc.

4.8.2 Where a unit is required to operate at locations exposed to wind waves and swell waves acting simultaneously then this is to be taken into account when determining the wave loads.

4.9 Wave loads

4.9.1 Design wave criteria specified by the Owner/designer may be described either by means of design wave energy spectra or deterministic design waves having appropriate shape, size and period. The following should be taken into account:

(a) The maximum design wave heights specified for each operating condition should be used to determine the maximum loads on the structure and principal elements. Consideration is to be given to waves of less than maximum height, where due to their period, the effects on various structural elements may be greater.
(b) Wave lengths are to be selected as the most critical ones for the response of the structure or element to be investigated.
(c) An estimate is to be made of the probable wave encounters that the unit is likely to experience during its service life in order to assess fatigue effects on its structural elements.

(d) When units are to operate in intermediate or shallow water, the effect of the water depth on wave heights and periods and of refraction due to sea bed topography is to be taken into account.

4.9.2 The forces produced by the action of waves on the unit are to be taken into account in the structural design, with regard to forces produced directly on the immersed elements of the unit and forces resulting from heeled positions or accelerations due to its motion. Theories used for the calculation of wave forces and selection of relevant coefficients are to be acceptable to LR.

4.9.3 The wave forces may be assessed from tests on a representative model of the unit by a recognised laboratory, *see Pt 4, Ch 3, 4.1 General 4.1.5* and *Pt 4, Ch 3, 4.1 General 4.1.6*.

4.9.4 Wave theories used for the calculation of water particle motions are to be acceptable to LR and when using acceptable wave theories for wave force determination, reliable values of C_{D} and C_{M} which have been obtained experimentally for use in conjunction with the specific wave theory are to be used. Otherwise published data are to be used.

4.9.5 Consideration is to be given to the possibility of wave impact and wave induced vibration in the structure, including superstructures.

4.9.6 Where sea current acts simultaneously with waves, the effect of the current is to be included in the load estimation. In those cases this superposition is deemed necessary, the current velocity should be added vectorially to the wave particle velocity. The resultant velocity is to be used to compute the total force.

4.9.7 The following methods may be used for load estimation:

(a) The forces on structural elements with dimensions less than 0,2 of the wave length subject to drag/inertia loading due to wave and current motions can be calculated from the Morison's equation:

$$F = 0{,}5 C_{\mathrm{D}}\, \rho\ A_{\mathrm{u}}\, \mathrm{IuI} + \mathrm{C}_{\mathrm{M\ r}\rho}\, \mathrm{V\ a}$$

where

F = force per unit length of member

C_{D} = drag coefficient

ρ = density of water

A = projected area of member per unit length

u = component of the water particle velocity at the axis of the member and normal to it (calculated as if the member were not there)

IuI = modulus of u

C_{M} = inertia coefficient

V = volume of water per unit length

a = component of the water particle acceleration at the axis of the member and normal to it (calculated as if the member were not there)

(b) Overall loading on an offshore structure is determined from the summation of loads on individual members at a particular time. The proper values of C_{D} and C_{M} for individual members to use with Morison's equation will depend on a number of variables, for example: Reynolds number, Keulegan-Carpenter number, inclination of the member to local flow and effective roughness of marine growth. Therefore, fixed values for all conditions cannot be given. Typical values for circular cylindrical members, will range from 0,6 to 1,4 for C_{D} and 1,3 to 2,0 for C_{M} . The values selected are not to be smaller than the lower limits of these ranges. For inclined members, the drag forces in Morison's equation are to be calculated using the normal component of the resultant velocity vector.

(c) General values of hydrodynamic coefficients may be used in the Morison's equation for the calculation of overall loading on the structure, namely:

- For circular cylinders covered by hard marine growth, C_{D} is to be not less than 0,7.
- For circular cylinders not covered by hard marine growth, C_{D} is to be not less than 0,6.

- For circular cylinders, C_M is to be not less than 1,7.

(d) Diffraction theory is normally appropriate to determine wave loads where the member is large enough to modify the flow field.

4.9.8 Account is to be taken of the increase of overall size and roughness of submerged members due to marine growth when calculating loads due to wave and current, *see Pt 4, Ch 3, 4.13 Marine growth*.

4.10 Inertia loads

4.10.1 Dynamic loads imposed on the structure by accelerations due to the unit's motion in a seaway are to be included in the structural design calculations. The dynamic loads may be obtained from model test results or by calculation. The methods of calculation are to be acceptable to LR.

4.11 Mooring loads

4.11.1 Mooring loads are to be considered for units operating afloat with positional mooring systems, *see Pt 3, Ch 10 Positional Mooring Systems*. The following are to be considered:

- The overall strength of the structure.
- The local strength where the mooring line forces are transmitted to the hull.

4.11.2 The support structure in way of mooring equipment is to be designed for the minimum design breaking load of the mooring line, determined in accordance with *Pt 3, Ch 10 Positional Mooring Systems*. *See also Pt 4, Ch 6, 1 General requirements*.

4.12 Snow and ice loads

4.12.1 Consideration is to be given to the extent to which snow and ice may accumulate on the exposed structure under any particular weather conditions. The wind resistance of exposed structural elements will be increased by the growth of ice. Details of the thickness and distribution of accumulation are to be established and taken into account in the design, *see also Pt 3, Ch 6 Units for Transit and Operation in Ice*.

4.12.2 The increased loading caused by the accumulation of snow and ice on any part of the structure is to be taken into account.

4.12.3 Values for the thickness, density and variation with height of accumulated snow and ice are to be derived from meteorological data acceptable to LR.

4.12.4 The overall distribution of snow and/or ice on topside structure is to be taken as a thickness t_{i} on the upper and windward faces of the deck structures or members under consideration, where t_{i} is the basic thickness obtained from the meteorological data. The distribution of ice on individual members may be assumed to be as shown in *Pt 4, Ch 3, 4.12 Snow and ice loads 4.12.6*.

4.12.5 It may be assumed that there is no increase of drag coefficient in the presence of ice.

4.12.6 The appropriate combinations of snow and ice loadings with other design environmental loads are to be specially considered and agreed with LR. In general, extreme snow and ice loads are to be combined with other environmental loads corresponding to the design five-year return criteria for the unit.

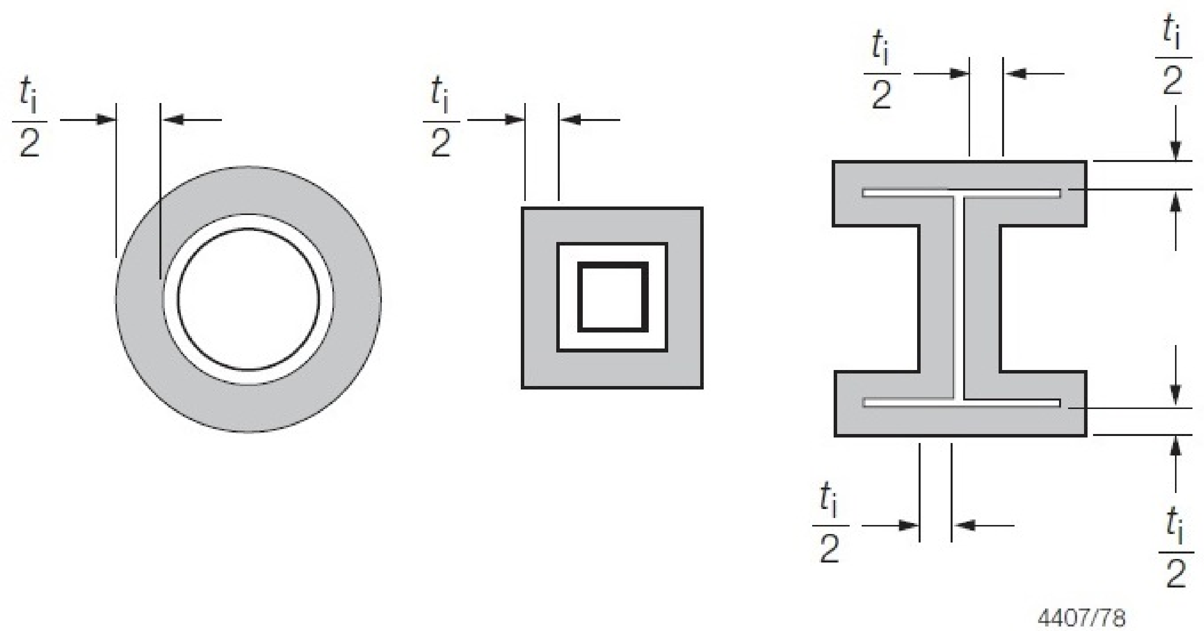


Figure 3.4.1 Assumed distribution of ice on individual members for calculation purposes

4.13 Marine growth

4.13.1 Marine growth will increase the weight and the overall dimensions of submerged members and alter their surface characteristics. These effects will increase the loads applied to the structure. The thickness of marine growth taken into account in the design is to be stated in the Operations Manual and the design limit is not to be exceeded in service. Unless more accurate data is available from the marine fouling study, the density of marine growth in air is to be taken as 1325 kg/m^3.

4.14 Hydrostatic pressures

4.14.1 The hydrostatic pressure head to be used as the basis for the design of internal spaces is to be the greatest of the following:

(a) For tanks, the maximum head during normal operation.
(b) For shell boundaries, the hydrostatic head due to external sea pressure.
(c) For watertight boundaries, the head measured to the worst damage waterline, *see Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

The minimum design pressure heads for local strength are to be in accordance with Chapter 6.

4.14.2 Where testing the tank involves pressure heads in excess of those derived in *Pt 4, Ch 3, 4.14 Hydrostatic pressures 4.14.1*, the excess may be taken into account by the use of a load factor applied to the design head. Where this is done, it is to be clearly stated in the calculations.

4.15 Deck loads

4.15.1 The maximum design uniform and concentrated deck loads for all areas of the unit in each mode of operation are to be taken into account in the design. The minimum design deck loads for local strength are to be in accordance with *Pt 4, Ch 6 Local Strength*.

4.16 Accidental loads

4.16.1 The following credible failures and accidents are to be considered in the design as applicable to the function of the unit:

- Collision.
- Dropped object.
- Blast.
- Accidental flooding.
- Loss of primary bracing (column-stabilised unit).
- Emergency helicopter landings.

4.16.2 Collision loads imposed by attending vessels which may be approaching, mooring or lying alongside the unit are to be considered in the design. The unit is to be designed to withstand accidental impacts between attending vessels and the unit and be capable of absorbing the impact energy.

Recommended practice is given in LR's *Guidance Notes for Collision Analysis* to assist in identifying potential collision scenarios, establishing representative collision loads and assessing the impact of these loads on structural integrity.

4.16.3 The kinetic energy to be considered is normally not to be less than:

- 14 MJ for sideway collision;
- 11 MJ for bow or stern collision;

corresponding to an attending vessel of 5000 tonnes displacement with impact velocity 2 m/s.

4.16.4 A reduced impact energy may be accepted upon special consideration, taking into account the environmental design criteria.

4.16.5 The energy absorbed by the unit during a collision impact will be less than or equal to the total impact kinetic energy, depending on the relative stiffnesses of the relevant parts of the unit and the impacting ship/unit and also on the mode of collision and ship/unit operation. These factors may be taken into account when considering the energy absorbed by the unit, *see also Pt 4, Ch 4, 1 Column-stabilised units* and *Pt 4, Ch 4, 3 Self-elevating units* for column-stabilised and self-elevating units respectively.

4.16.6 Collision is to be considered for all elements of the unit which may be hit by sideway, bow or stern collision. The vertical extent of the collision zone is to be based on the depth and draught of attending ships/units and the relative motion between the attending ships/units and the unit.

4.16.7 The accidental impact loads caused by dropped objects from cranes are to be considered in the design of the unit when the arrangements of the unit are such that the failure of a vital structure member could result in the collapse of the structure.

4.16.8 Critical areas for dropped objects are to be determined on the basis of the actual movement of crane loads over the unit.

4.16.9 The structural bulkheads protecting accommodation areas, and other structures that may be subject to blast pressures, are to be designed for accidental blast loading, where applicable. The design blast pressures are to be defined by the Owners/ designers, *see Pt 7, Ch 3, 2.4 Fire and Explosion Evaluation (FEE) 2.4.2* and are to comply with National requirements. Blast loads are to be combined with the still water loads. Environmental loads need not be considered. Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods, *see also Pt 4, Ch 3, 4.16 Accidental loads 4.16.11*.

4.16.10 Accidental flooding of a single hull compartment is to be considered in the design of the unit. As a minimum, the compartments to be addressed are to include those set out in *Chapter 3 - Subdivision, Stability and Freeboard* as applicable to the unit type. Special consideration will be given to unit types not addressed by the 2009 IMO MODU Code.

4.16.11 Units with slender members where the failure of a single member could result in the overall collapse of the unit's structure are to be considered for credible failure of such members, *see Pt 4, Ch 4 Structural Unit Types*.

4.16.12 Requirements for helicopter landing areas are given in *Pt 4, Ch 6, 5 Helicopter landing areas*.

4.16.13 Permissible stresses for accidental load conditions are given in *Pt 4, Ch 5, 2 Permissible stresses*.

4.16.14 When a National Administration in the country in which the unit is registered and/or in which it is to operate has additional requirements for accidental loads these are to be taken into account in the design loadings.

4.17 Fatigue design

4.17.1 Fatigue damage due to cyclic loading must be considered in the design of all unit types.

4.17.2 Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in *Pt 4, Ch 5, 5 Fatigue design* or other acceptable method.

4.17.3 The factors of safety on calculated fatigue life are to comply with *Pt 4, Ch 5, 5 Fatigue design*. Additional factors of safety are given in*Pt 10, Ch 1, 19 Fatigue* for ship units.

4.18 Other loads

4.18.1 If attending ships/units are to be moored to the unit, the forces imposed by the moorings on the structure are to be taken into account in the design.

4.18.2 Other local loads imposed on the structure by equipment and mooring and towing systems are to be considered in the design of the structure.

4.18.3 When partial filling of tanks is contemplated in operating conditions, the risk of significant loads due to sloshing induced by any of the vessel motions is to be considered. An initial assessment is to be made to determine whether or not a higher level of sloshing investigation is required, using the procedure given in *Pt 3, Ch 3, 5 Design loading* of the Rules for Ships.

■ *Section 5*
Number and disposition of bulkheads

5.1 General

5.1.1 The number and disposition of watertight bulkheads are to be arranged to ensure adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. They are also to be in accordance with the requirements of the National Administration in the country in which the unit is registered and/or in which it is to operate, *see Pt 1, Ch 2, 1 Conditions for classification* and *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

5.1.2 Bulkheads are to be spaced at reasonable uniform intervals. Where, due to the design of a unit, the spacing of bulkheads is unusually great, the transverse strength of the unit is to be maintained by fitting suitable web frames between the bulkheads. Details of bulkheads and intermediate web frames are to be submitted for approval.

5.1.3 The requirements of *Pt 4, Ch 3, 5.3 Column-stabilised units 5.3.3* are to be complied with as applicable.

5.2 Self-elevating units

5.2.1 The arrangement of longitudinal and transverse bulkheads are to satisfy the overall strength requirements given in *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength* when the unit is in the elevated position and when afloat.

5.2.2 The number and arrangement of watertight bulkheads are to meet the requirements of damage stability.

5.2.3 Watertight bulkheads are to extend to the uppermost continuous deck.

5.3 Column-stabilised units

5.3.1 The arrangement of watertight bulkheads and flats are to be made effective to that point necessary to meet the requirements of damage stability.

5.3.2 The arrangement of longitudinal and transverse bulkheads in the upper and lower hulls and in columns are to satisfy the overall strength requirements given in *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength*.

5.3.3 The subdivision and arrangement of bulkheads and cofferdams on production and oil storage units are also to comply with *Pt 3, Ch 3 Production and Storage Units*.

5.4 Buoys and deep draught caissons

5.4.1 The number and arrangement of structural bulkheads are to satisfy the overall strength requirements in *Pt 4, Ch 5 Primary Hull Strength*. The requirements of *Pt 4, Ch 3, 5.1 General 5.1.1* and *Pt 4, Ch 3, 5.3 Column-stabilised units 5.3.3* are to be complied with.

5.5 Tension-leg units

5.5.1 In general, the number and arrangement of structural bulkheads are to comply with *Pt 4, Ch 3, 5.3 Column-stabilised units*.

5.6 Protection of tanks carrying fuel oil and lubricating oil

5.6.1 The requirements for the protection of tanks carrying fuel oil and lubricating oil, which are given in *Pt 3, Ch 3, 4.7 Protection of tanks carrying fuel oil, lubricating oil, vegetable or similar oils* of the Rules for Ships, are to be complied with, as applicable.

■ *Section 6*
Procedures for testing tanks and tight boundaries

6.1 General

6.1.1 The test procedures detailed in this Section are to be used to confirm the watertightness of tanks and watertight boundaries, the structural adequacy of tanks and weathertightness of structures.

6.2 Application

6.2.1 The testing requirements for gravity tanks, defined as tanks subject to a vapour pressure not greater than 70 kN/m^2, and other boundaries required to be watertight or weathertight, are to be tested in accordance with this Section. Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired and prior to any ceiling and cement work being applied over joints.

6.2.2 The testing of structures not listed in this Section are to be specially considered.

6.3 Test types

6.3.1 The types of test specified in this Section are:

(a) **Structural test:** which is to be conducted to verify the tightness and structural adequacy of the construction of tanks. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

(b) **Leak test:** which is to be used to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic, hydropneumatic test, air or other medium test.

6.4 Structural test procedures

6.4.1 Where a structural test is specified in *Pt 4, Ch 3, 6.8 Safe access to joints 6.8.1*, unless specified otherwise, a hydrostatic test is to be carried out in accordance with *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.1*. Where practical limitations prevent a hydrostatic test being carried out, a hydropneumatic test in accordance with *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.2* is to be conducted.

6.4.2 A hydrostatic test may be carried out afloat to confirm the structural adequacy of tanks, provided a leak test is carried out beforehand and the results are confirmed as satisfactory.

6.4.3 For tanks of the same structural design, configuration and the same general workmanship, as determined by the attending Surveyor, a structural test may be carried out on only one tank, provided all subsequent tanks are tested for leaks by an air test.

6.4.4 Where the structural adequacy of a tank has been verified by structural testing on a previous vessel in a series, tanks of structural similarity on subsequent vessels within that series may be exempt from such testing, provided that the watertightness of all exempt tanks is verified by leak tests and thorough inspection. For sister ships built several years after the last ship in a series, such exemptions may be reconsidered. However, structural testing is to be carried out for at least one tank on each vessel in the series in order to verify structural fabrication adequacy. The relaxation to accept leak testing and thorough inspections instead of a structural test on subsequent vessels in a series does not apply to cargo space boundaries and tanks for segregated cargoes or pollutants.

6.4.5 Tanks exempted from structural testing in *Pt 4, Ch 3, 6.4 Structural test procedures 6.4.3* and *Pt 4, Ch 3, 6.4 Structural test procedures 6.4.4* may require structural testing if found necessary after the structural testing of the first tank.

6.4.6 For watertight boundaries of spaces other than tanks, excluding chain lockers, structural testing may be exempted, provided that the watertightness in all boundaries of exempted spaces are verified by leak tests and thorough inspection.

6.4.7 Consideration is to be given to the selection of tanks to be structurally tested. Selected tanks should be chosen so that all representative structural members are tested for the expected tension and compression.

6.5 Leak test procedures

6.5.1 Where a leak test is specified in *Pt 4, Ch 3, 6.8 Safe access to joints 6.8.1*, unless specified otherwise, a tank air test, compressed air fillet weld test, or vacuum box test is to be carried out in accordance with the applicable requirements of *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.4* to *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.6*. A hydrostatic or hydropneumatic test conducted in accordance with the applicable requirements of *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.1* and *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.2* will be accepted as a leak test.

6.5.2 A hose test will be accepted as means of verifying the tightness of joints only in specific locations, identified in *Pt 4, Ch 3, 6.8 Safe access to joints 6.8.1*.

6.5.3 Air tests of joints may be conducted at any stage during construction provided that all work that might affect the tightness of the joint is completed before the test is carried out.

6.6 Definitions and details of tests

6.6.1 **Hydrostatic test** is a test conducted by filling a space with a liquid to a specified head. Unless another liquid is approved, the hydrostatic test is to consist of filling a space with either fresh or sea-water, whichever is appropriate for the space being tested, to the level specified in *Pt 4, Ch 3, 6.8 Safe access to joints 6.8.1*. For tanks intended to carry cargoes of a higher density than the test liquid, the head of the liquid is to be specially considered.

6.6.2 **Hydropneumatic** test is a combination of a hydrostatic test and a tank air test, consisting of partially filling a tank with water and conducting a tank air test on the unfilled portion of the tank. A hydropneumatic test, where approved, is to be such that the test condition in conjunction with the approved liquid level and air pressure will simulate the actual loading as far as practicable. The requirements for tank air testing shown in *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.4* are to be adhered to.

6.6.3 **Hose test** is a test used to verify the tightness of joints with a jet of water. It is to be carried out with the pressure in the hose nozzle maintained at not less than 2,0 bar during the test. The hose nozzle is to have a minimum inside diameter of 12 mm and is to be situated no further than 1,5 m from the joint. Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by a careful visual examination of welded connections, supported by an ultrasonic or penetration leak test, or an equivalent, *see* SOLAS Reg. II-1/*Regulation 11 - Initial testing of watertight bulkheads, etc.*.

6.6.4 **Tank air test** is to be used to verify the tightness of a compartment by means of an air pressure differential and leak detection solution. An efficient indicating solution (e.g., soapy water) is to be applied to the weld or penetration being tested and is to be examined whilst an air pressure differential of not less than 0,15 bar is applied by pumping air into the compartment. It is recommended that the air pressure in the tank be raised to and maintained at 0,20 bar above atmospheric pressure for one hour, with a minimum number of personnel in the vicinity of the tank, before being lowered to 0,15 bar above atmospheric pressure. Arrangements are to be made to ensure that any increase in air pressure does not exceed 0,30 bar. A U-tube with a height sufficient to hold a head of water corresponding to the required test pressure is to be used for verification and to avoid overpressure. The cross-sectional area of the Utube is not to be less than that of the pipe supplying air to the tank. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system. All boundary welds, erection joints and penetrations including pipe connections in the compartment are to be examined.

6.6.5 **Compressed air fillet weld test**. This test consists of compressed air being injected into one end of a fillet welded joint and the pressure verified at the other end of the joint by a pressure gauge on the opposite side. Pressure gauges are to be arranged so that an air pressure of at least 0,15 bar above atmospheric pressure can be verified at each end of all passages within the portion being tested. A leak indicator solution is to be applied and the weld line examined for leaks. A compressed air test may be carried out for partial penetration welds where the root face is greater than 6 mm.

6.6.6 **Vacuum box test** is a test used to verify the tightness of joints by means of a localised air pressure differential and indicator solution. The test is to be conducted with the use of a box with air connections, gauges and an inspection window that is to be placed over the joint being tested with a leak indicator solution applied. Air within the box is to be removed by an ejector to create a reduction in pressure. The pressure inside the box during the test is to be maintained between 0,20 to 0,26 bar.

6.6.7 **Ultrasonic test** may be used where a hose test is not practical to verify the tightness of a boundary, *see Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.3*. An arrangement of ultrasonic echo transmitters is to be placed inside a compartment and a receiver outside. The receiver is to be used to detect any leaks in the compartment.

6.6.8 **Penetration test** may be used where a hose test is not practical to assess butt welds, *see Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.3*, by applying a low surface tension liquid to one side of a compartment boundary. When no liquid is detected on the opposite side of the boundary after expiration of a definite time, the verification of tightness of the compartment's boundary may be assumed.

6.6.9 Other methods of testing may be considered and are to be agreed by LR prior to commencement of testing.

6.7 Application of coating

6.7.1 A final coating may be applied over automatic butt welds before the completion of a leak test, provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of selected NDE testing show no significant defects. For all other joints, the final coating is to be applied after the completion of a leak test. The Surveyor reserves the right to require a leak test prior to the application of the final coating over automatic erection butt welds.

6.7.2 Any temporary coating which may conceal defects or leaks is to be applied at a time as specified for the final coating, *see Pt 4, Ch 3, 6.7 Application of coating 6.7.1*. This requirement does not apply to shop primer.

6.8 Safe access to joints

6.8.1 For leak tests, safe access to all joints under examination is to be provided.

Table 3.6.1 Testing requirements

Item to be tested	Testing procedure	Test requirement
Double bottom tanks, *see* Note 1	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to bulkhead deck
Combined double bottom and hopper side tanks	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water representing the maximum pressure experienced in service
Double bottom voids, *see* Note 3	Leak	
Double side tanks	Leak & structural	The greater of:
Combined double bottom, lower hopper and topside tanks	Leak & structural	• head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Topside tanks	Leak & structural	• head of water up to bulkhead deck
Double side voids	Leak	
Deep tanks (other than those listed)	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Cargo oil tanks, and fuel oil bunkers	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Scupper and discharge pipes in way of tanks	Leak & structural	• head of water up to top of tank, *see* Note 2, plus setting of fitted pressure-relief valve

Ballast hold of bulk carriers	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water up to the top of cargo hatch coaming
Peak tanks, *see* Note 4	Leak & structural	The greater of:: • head of water up to the top of the overflow • head of water 2,4 m above top of tank, *see* Note 2
Fore peak voids	Leak	
Aft peak voids, *see* Note 4	Leak	
Cofferdams	Leak	
Watertight bulkheads	Leak	*See* Note 5
Superstructure end bulkhead	Leak	
Watertight doors below freeboard or bulkhead deck	Leak	*See* Notes 5 & 6
Double plate rudder blade	Leak	
Shaft tunnel clear of deep tanks	Leak	*See* Note 5
Shell doors when fitted in place	Leak	*See* Notes 5 & 7
Weathertight hatch covers and closing appliances	Leak	*See* Note 5
Steel hatch covers fitted to the cargo oil tanks and cargo holds of ships used for the alternate carriage of oil cargo and dry bulk cargo	Leak	*See* Note
Chain locker	Leak & structural	Head of water up to top of chain pipe
Independent tanks, and edible liquid tanks	Leak & structural	The greater of: • head of water up to the top of the overflow • head of water 0,9 m above top of tank, *see* Note 2
Ballast ducts	Leak & structural	The greater of: • ballast pump maximum pressure • setting of pressure-relief valve

Chemical tanker cargo tanks	Leak & structural	The greater of: • head of water 2,4 m above top of tank, *see* Note 2 • head of water up to top of tank, *see* Note 2, plus setting of fitted pressure-relief valve

NOTES

1. Including tanks arranged in accordance with the provisions of SOLAS Reg. II-1/*Regulation 9 - Double bottoms in passenger ships and cargo ships other than tankers*.

2. Top of tank is the deck forming the top of the tank, excluding any hatchways. In holds for liquid cargo or ballast with large hatch openings, the top of tank is to be taken to the top of the hatch.

3. Including duct keels and dry compartments arranged in accordance with the provisions of SOLAS Reg. II-1/*Regulation 9 - Double bottoms in passenger ships and cargo ships other than tankers*.

4. Testing of the aft peak is to be carried out after the sterntube has been fitted.

5. A hose test will be considered, *see Pt 4, Ch 3, 6.5 Leak test procedures 6.5.2* and *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.3*.

6. Watertight doors not confirmed watertight by a prototype test are to be subject to a hydrostatic test, *see* SOLAS Reg. II-1/*Regulation 16 - Construction and initial tests of watertight doors, sidescuttles, etc.*.

7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR prior to testing.

8. Other testing methods listed in *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.7* and *Pt 4, Ch 3, 6.6 Definitions and details of tests 6.6.8* may be considered, subject to adequacy of such testing methods being verified, *see* SOLAS Reg. II-1*Regulation 11 - Initial testing of watertight bulkheads, etc.*

■ *Section 7* Corrosion additions

7.1 General

7.1.1 The net scantling approach is described in *Pt 4, Ch 3, 7.2 Net scantling approach*. Corrosion additions are defined in *Pt 4, Ch 3, 7.3 Corrosion additions* and in-operation steel renewal criteria are defined in *Pt 1, Ch 3, 1.10 Steel renewal criteria*.

7.1.2 The requirements for corrosion protection given in *Pt 8 CORROSION CONTROL* are to be complied with.

7.2 Net scantling approach

7.2.1 The net thickness of a structural element is that required for structural strength compliance with the design basis. The corrosion addition for structural elements is derived independently of the net scantling requirements. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the in-operation phase. This approach enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the unit. *See Figure 3.7.1 Example calculations of corrosion additions*.

7.2.2 The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas such as primary support members and the hull girder.

7.3 Corrosion additions

7.3.1 The corrosion additions specified in this sub-Section are applicable to each of the two sides of a structural member and are given as a corrosion rate. The corrosion rate for each of the two sides of a structural member is specified in *Table 3.7.1 Corrosion rate for one side of structural member*. However, consideration will be given to alternative corrosion rates if these are contractually agreed between the Owner and Shipyard.

7.3.2 The total corrosion addition for a structural member is given by the following formula:

$t_c = N_c (t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,5 mm

where

N_c = number of years of unit life where coating is not fully effective, *see Figure 3.7.2 Generic example unit life cycle*. N_c is not to be less than 10 years for new-builds and not less than 5 years for conversions and redeployments where coating is not renewed. Where cargo tanks remain uncoated, N_c is to be taken as equal to the unit design life

t_{c1}, t_{c2} = corrosion rate for each side of the structural member, as given in *Table 3.7.1 Corrosion rate for one side of structural member*

For example calculations of corrosion additions, *see Figure 3.7.1 Example calculations of corrosion additions*.

7.3.3 The corrosion rates for cargo and ballast water tanks given in *Table 3.7.1 Corrosion rate for one side of structural member* assume the tanks will spend 50 per cent of the time empty and 50 per cent of the time full over the unit design life and that the ballast tank is fitted with effective anodes. Where alternative regimes for individual tanks are specified, the corrosion rate may be adjusted by [percentage time empty/50] x corrosion rate from *Table 3.7.1 Corrosion rate for one side of structural member*. The percentage time empty is not to be taken as less than 25 per cent.

7.3.4 The default coating life is to be taken as 15 years. Alternative corrosion additions may be derived using the general principles shown in *Figure 3.7.2 Generic example unit life cycle* where an alternative coating life is specified.

7.3.5 To address the risk of pitting corrosion, the gross thickness of the bottom plating of tanks is not to be less than:

$$t_{grs} = 6 + N_t (20t_{c1} + t_{c2})$$

where

N_t = number of years between surveys (not to be taken as less than 5 for new builds or 2,5 for conversions)

t_{c1} and t_{c2} are defined in *Pt 4, Ch 3, 7.3 Corrosion additions 7.3.2*. t_{c1} is the value for the side of the structural member within the tank.

Explanatory note:

This requirement ensures that there is sufficient bottom plating thickness remaining at thickness measurement survey so that pitting corrosion should not lead to loss of barrier integrity between inspections.

7.4 Scantling compliance

7.4.1 The minimum net thicknesses of structural items as required by Chapter 3 are to be rounded to the nearest 0,5 mm prior to the addition of Owner's extras or corrosion additions. The applicable corrosion additions are given in *Pt 4, Ch 3, 7.3 Corrosion additions*.

7.4.2 The net section modulus, moment of inertia and shear area properties of local support members are to be calculated using the net thicknesses of the attached plate, web and flange.

7.4.3 The net section properties, shear area and section modulus of primary support members are to be calculated using the net thicknesses of the attached plate, web and flange plus half of the applicable corrosion addition specified in *Pt 4, Ch 3, 7.3 Corrosion additions*.

7.4.4 The net scantlings described in this sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in *Pt 4, Ch 3, 7.3 Corrosion additions*;

(b) for plating and local support members, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Pt 4, Ch 3, 7.3 Corrosion additions*;

(c) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in *Pt 4, Ch 3, 7.3 Corrosion additions*;

(d) for application of buckling requirements, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in *Pt 4, Ch 3, 7.3 Corrosion additions*.

7.4.5 Any additional thickness specified by the Owner as Owner's extra margin is not to be included when considering compliance with this Section.

7.4.6 The corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment is given in *Table 3.7.2 Corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment*.

Table 3.7.1 Corrosion rate for one side of structural member

Compartment type	Structural member	Corrosion rate t_{c1}, t_{c2}(mm/year)
Ballast water and preload tanks (*see* Note 5)	within 3m below top of tank, *see* Note 1	0,15
	Elsewhere	0,1
Cargo oil tank	within 3m below top of tank, *see* Note 1	0,125
	Bottom of single bottom tanks	0,125
	Elsewhere	0,075
Exposed to atmosphere	Weather deck plating	0,1
	Other members	0,075
Exposed to sea water (*see* Notes 5 and 6)	Shell plating	0,075
	Legs of self-elevating units	0,075
Exposed to sea bed and seawater	Legs, footings, mats of self-elevating units	0,2 (*see* Note 7)
Fuel and lubricating oil tank *see* Note 3		0,05
Fresh water tank		0,05
Slop tanks		0,015
Void spaces, *see* Note 2	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space common with a dry bulk cargo hold, etc.	0,05
Dry spaces	Internals of machinery spaces, pump room, store rooms, steering gear space, etc	0,05
Hold space bounding membrane liquefied gas tanks	side of hull structure within hold space where there is environmental control such as inerting	0

Note 1 This is only applicable to cargo tanks and ballast tanks with weather deck as the tank top.

Note 2. The corrosion rate on the outer shell plating in way of a pipe tunnel is to be taken as for a water ballast tank.

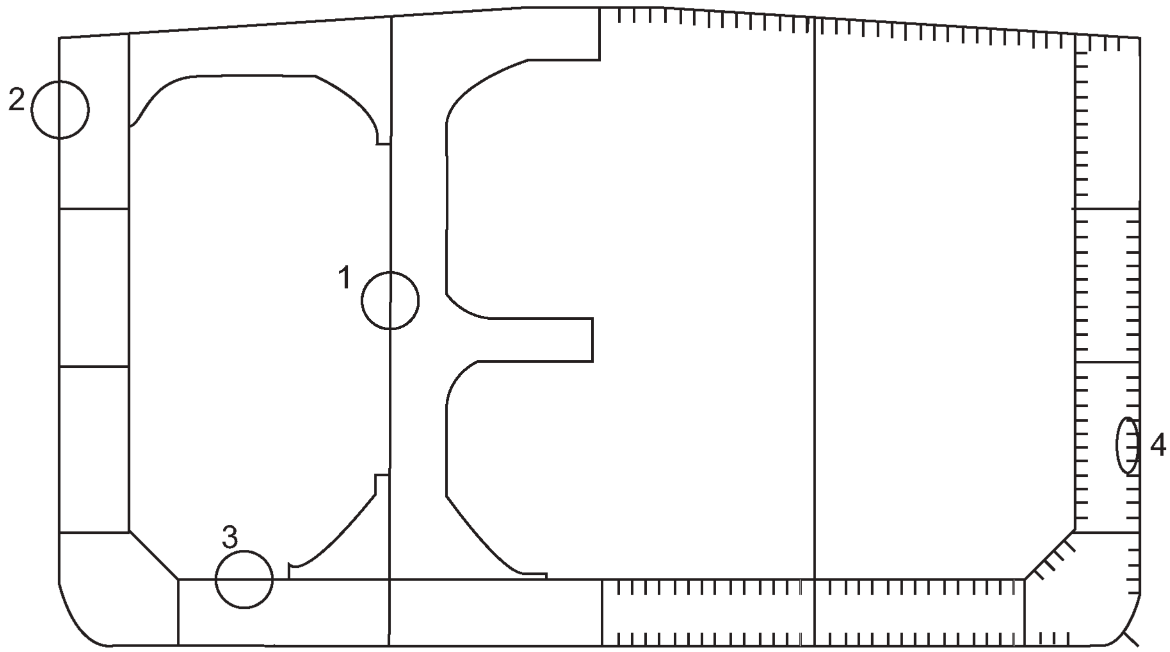
Note 3. 0,07 mm/year is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks. 0,03 mm/year is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks. Heated cargo oil tanks are defined as tanks arranged with any form of heating capability.

Note 4. Where a tank is loaded with contents not listed in Table 1.3, e.g. drilling mud, corrosion rates will be specially considered.

Note 5. The Corrosion rates indicated assume effective anodes are fitted to the steel boundary.

Note 6. Additional corrosion allowance in the splash zone is recommended.

Note 7. Additional margins greater than those indicated in the table may be required where the members are subject to high corrosion/ wear rates.



1 **Longitudinal bulkhead plating**

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,075 mm/year for each side of the plating

Unit design life = 25 years

Effective coating life = 15 years

Total corrosion addition = (25-15) x (0,075 + 0,075) = 10 x 0,15 = 1,5 mm

2 **Side shell plating (within 3 m below top of tank**

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,075 mm/year for each side shell plating

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,15 mm/year for ballast water tank

Unit design life = 25 years

Effective coating life = 15 years

Total corrosion addition = (25-15) x (0,075 + 0,15) = 10 x 0,225 = 2,25 mm = 2,5 mm rounded

3 **Cargo tank bottom plating**

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,075 mm/year for cargo tank plating

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,1 mm/year for ballast water tank

Unit design life = 25 years

Effective coating life = 15 years

Total corrosion addition = (25-15) x (0,075 + 0,1) = 10 x 0,175 = 1,75 mm = 2 mm rounded

4 **Stiffeners in ballast water tank**

Corrosion addition (*Table 3.7.1 Corrosion rate for one side of structural member*) = 0,1 mm/year for ballast water tank

Unit design life = 25 years

Effective coating life = 15 years

Total corrosion addition = (25-15) x (0,1 + 0,1) = 10 x 0,2 = 2 mm

Note This example assumes that the tanks will spent 50 per cent of the time empty and 50 per cent of the time full over the unit design life.

Figure 3.7.1 Example calculations of corrosion additions

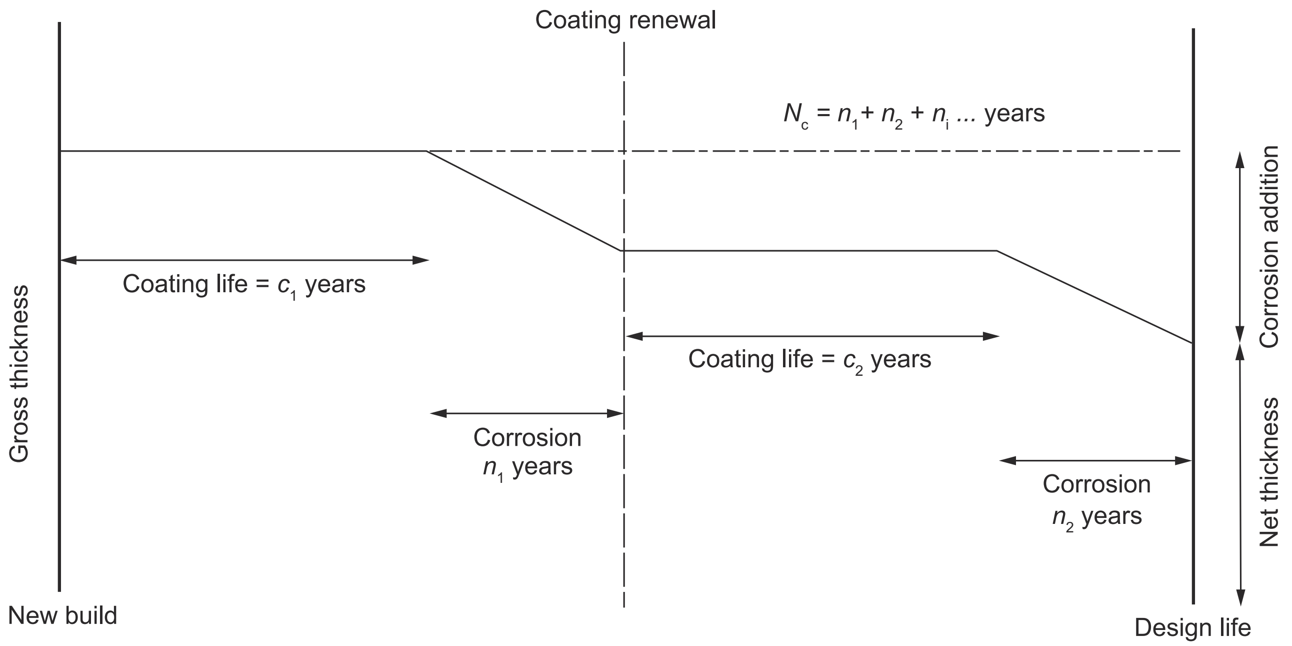


Figure 3.7.2 Generic example unit life cycle

Table 3.7.2 Corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment

Assessment		Stress calculations	Buckling capacity calculations
Minimum thickness	Thickness	t_c	N/A
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties	t_c	N/A
	Stiffness/proportions	t_c	t_c
Primary support members (Prescriptive)	Thickness/sectional properties	0,5 t_c	N/A
	Stiffness/proportions of web and flange	t_c	t_c
Strength	Global coarse mesh	0,5 t_c	t_c
	Local fine mesh	t_c	
Fatigue	Global coarse mesh	0,25 t_c	N/A
	Local fine mesh	0,5 t_c	
Sloshing	Sloshing	t_c	t_c

Fracture	Global coarse mesh	0,25 t_c	N/A
	Local extremely fine mesh	0,5 t_c	
Ultimate strength	Ultimate strength	0,5 t_c	0,5 t_c
Note For the assessment, the gross scantling used is not to include any Owner's extra.			

■ *Section 1* Column-stabilised units

1.1 General

1.1.1 This Section outlines the structural design requirements of column-stabilised (semi-submersible) units as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*. Additional requirements for particular unit types related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

1.1.2 Units which are required to operate while resting on the sea bed are also to comply with the requirements of *Pt 4, Ch 4, 2 Sea bed-stabilised units*.

1.1.3 Production and oil storage units are to comply with the requirements of*Pt 3, Ch 3 Production and Storage Units*. Columns and pontoons designed for the storage of oil in bulk storage tanks are to be of double hull construction. If pontoon oil storage tanks are always kept empty in transit conditions, a double bottom need not be fitted, except where a double bottom is required by a National Administration and/or Coastal State Authority.

1.1.4 If it is intended to dry-dock the unit, the bottom structure is to be suitably strengthened to withstand the loadings involved. The proposed docking arrangement plan and maximum bearing pressures are to be submitted.

1.2 Air gap

1.2.1 In all floating modes of operation, column stabilised units are normally to be designed to have a clearance 'air gap' between the underside of the upper hull deck structure (and any underdeck structure or critical equipment as applicable to the specific design) and the highest predicted design wave crest. The minimum clearance is not to be less than 1,5m, taking into account the most onerous conditions and the predicted motion of the unit relative to the surface of the sea. Calculations, model test results or prototype reports are to be submitted for consideration. Where necessary for operational purposes, any platforms or structures below the air gap are to be designed for the hydrodynamic forces encountered in waves present in these areas.

1.2.2 In cases where the unit is designed without a clearance air gap, the scantlings of the upper hull deck structure are to be designed for wave impact forces, *see also Pt 4, Ch 4, 1.4 Upper hull structure 1.4.4*.

1.3 Structural design

1.3.1 The general requirements for structural design are given in *Pt 4, Ch 3 Structural Design*, but the additional requirements of this Section are to be complied with.

1.3.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit in transit and semi-submerged conditions. All relevant loads as defined in *Pt 4, Ch 3 Structural Design* are to be considered and the permissible stresses due to the overall and local load effects are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*. The minimum local scantlings of the unit are to comply with *Pt 4, Ch 6 Local Strength*.

1.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in *Pt 4, Ch 5, 1.2 Structural analysis* are to be complied with. The loading conditions applicable to a column-stabilised unit are shown in *Pt 4, Ch 4, 1.3 Structural design 1.3.3*.

Table 4.1.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Operating	X	X	X	X
Survival	X	X	X	X
Transit	X	X	X	X

NOTES

1. For definition of loading conditions (a) to (d), *see Pt 4, Ch 3, 4.3 Load combinations*.

2. For loading conditions (c) and (d) as applicable to a column-stabilised unit, *see Pt 4, Ch 4, 1.3 Structural design 1.3.5* to *Pt 4, Ch 4, 1.3 Structural design 1.3.7*.

1.3.4 A strength and fatigue assessment of the special and primary structure is to be carried out by a three-dimensional finite element method in accordance with the LR ShipRight Procedure for Semi-submersibles.

1.3.5 In order to ensure adequate structural redundancy after credible failure or accidents, the structure is to be investigated for loading condition (d) in *Pt 4, Ch 4, 1.3 Structural design 1.3.3*. The environmental loads for this load case are to be taken as the same as determined for loading condition (b). The structure is to be able to withstand the following failures without causing the overall collapse of the unit's structure:

- The failure of any main primary bracing member.
- When the upper hull structure consists of heavy or box girder construction, the failure of any primary slender member.

1.3.6 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*, but in the case of a column-stabilised unit, collision loads against a column or pontoon will normally only cause local damage to the structure and consequently loading condition (c) in *Pt 4, Ch 4, 1.3 Structural design 1.3.3* need not be investigated from the overall strength aspects. The requirements for very slender columns will be specially considered.

1.3.7 The permissible stress levels after credible failures or accidents are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

1.4 Upper hull structure

1.4.1 Decks and supporting grillage structures forming part of the primary structure are to be designed to resist both the overall and local loadings.

1.4.2 Openings in primary bulkheads and decks are normally to be represented in the structural model. Bulkhead openings in 'tween decks are not, in general, to be fitted in the same vertical line. When large bulkhead openings are cut in the structure which were not included in the structural model, the bulkhead thickness is to be increased in way of the opening to compensate for the loss of shear area and stiffness.

1.4.3 When the primary deck structure consists of heavy or box girder construction and the infill deck plating is considered to be secondary structure, only the main deck girders and the secondary deck plating stiffeners need satisfy the buckling strength requirements given in *Pt 4, Ch 5 Primary Hull Strength*. The infill deck plating thickness and its contribution to the overall strength of the structure will be specially considered, *see also Pt 4, Ch 6, 4 Decks*.

1.4.4 When the upper hull structure is designed to be waterborne for operational purposes the upper hull scantlings are not to be less than those specified for shell boundaries of self-elevating units as defined in *Pt 4, Ch 6, 3 Watertight shell boundaries*.

1.4.5 Columns should be aligned and integrated with the bulkheads in the upper hull structure. Particular attention should be given to the detail design at the intersection of columns with the upper hull structure to minimise stress concentrations.

1.5 Columns

1.5.1 Columns are to be designed to withstand the forces and moments resulting from the overall loadings, together with forces and moments due to wave loadings and internal tank pressures.

1.5.2 In general, internal spaces within the columns are to be designed for the pressure heads defined in *Pt 4, Ch 3, 4.14 Hydrostatic pressures*.

1.5.3 High local loads are also to be taken into account in the overall design strength of the columns.

1.5.4 Internal column structure supporting main bracings is in general not to be of a lesser strength than the bracing itself.

1.5.5 When bracing forces are designed to be transmitted to the column shell, the resulting column shell stresses are to be combined with the stresses due to the hydrostatic pressure and overall forces.

1.6 Lower hulls

1.6.1 Lower hulls or pontoons are to be designed for overall bending, shear forces, and axial forces due to end pressure when combined with the local hydrostatic pressure as defined in *Pt 4, Ch 3, 4.14 Hydrostatic pressures*.

1.6.2 Irrespective of the tank loading arrangement, the scantlings of tanks are to be verified in both full and empty conditions.

1.6.3 Columns are, as far as practicable, to be continuous through the plating of the lower hull deck structure and be aligned and integrated with the internal bulkheads and/or side shell.

1.6.4 Where the column shell plating is intercostal with the lower hull deck, the deck plating below the columns is to be suitably increased and is to have steel grades with suitable through thickness properties, *see Pt 4, Ch 2, 4.1 General 4.1.3*.

1.6.5 Particular attention should be given to the design of the local structure at the intersection of columns with lower hulls and due account should be given to penetrations and stress concentrations.

1.7 Main primary bracings

1.7.1 Bracing members are to be designed to withstand the stresses imposed by the overall loading, together with local stresses due to wave, current and buoyancy forces and, when applicable, hydrostatic pressure.

1.7.2 Bracings are in general to be made watertight and provided with adequate means of access to enable internal inspection to be carried out when the unit is afloat.

1.7.3 Watertight bracings are to be designed for the hydrostatic pressure loads defined in*Pt 4, Ch 3, 4.14 Hydrostatic pressures*, and the scantlings are to be verified against buckling due to combined axial stresses and hoop stresses caused by external hydrostatic pressure. Ring stiffeners are to be fitted where necessary.

1.7.4 Attachments and penetrations to the shell of bracings are to be avoided as far as practicable. If attachments are unavoidable they are generally to be welded to suitable doubler plates having well rounded corners. Special consideration will be given to alternative proposals. In all cases the attachment is to be designed to minimise the resulting stress concentration in the brace and the fatigue life is to be checked.

1.7.5 Leak detection and drainage arrangements of watertight bracings are to be in accordance with *Pt 5, Ch 13, 3 Drainage of compartments, other than machinery spaces for column-stabilised units*.

1.7.6 The scantlings and arrangements of free-flooding bracings will be specially considered.

1.8 Bracing joints

1.8.1 Joints at the intersection of bracings or between bracings and columns are to be designed to transmit the bending, direct and shear forces involved in such a manner as to reduce, so far as possible, the risk of fatigue failure. Stress concentrations are to be minimised by good detail design and, in general, nominal stress levels are to be made lower than in the adjacent structure by increasing plate thickness or suitably flaring the member ends, or both. Ring stiffeners or other welded attachments across the principal stress direction are to be avoided wherever possible in all regions of high stress. It this is not possible (e.g., where required to support bracket ends on otherwise unstiffened plating), the weld is to have a smooth profile without undercutting. Continuity of strength is to be maintained through the joint, and shear web plates and other axial stiffening members are to be made continuous.

1.8.2 Special attention is also to be given to the qualities of bracing details, e.g., openings, penetrations, stiffener ends, brackets and other attachments. The welding procedure is to be such as to minimise the risk of cracks, lack of penetration and lamellar tearing of the parent steel.

1.8.3 Joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Plate steel used in such locations shall have suitable through thickness properties.

1.9 Lifeboat platforms

1.9.1 The strength of lifeboat platforms is to be verified with the unit in the upright condition and in the inclined condition at an angle corresponding to the worst damage waterline, and at an inclined angle of 15° in any direction.

1.9.2 For calculation purposes, the weight of the lifeboat is to be taken as the weight when fully manned and equipped. The platform weight is to be taken as the steel weight plus the weight of davits and equipment. Symmetrical and unsymmetrical load cases are to be considered as appropriate, e.g., one lifeboat launched and the other lowering. The design calculations are to be submitted for information.

1.9.3 The following dynamic load factors are to be included in the calculations:

Item:	Factor:
Platform weight	0,3 g
Lifeboat weight when stowed	0,3 g
Lifeboat weight when lowering	0,5 g

1.9.4 In the upright condition and in the inclined condition the permissible stresses are to comply with ,*Table 5.2.1 Factors of safety for the combined load cases* – load case (a) and load case (b).

1.9.5 After installation of the lifeboats, testing is to be carried out to the satisfaction of LR's Surveyors.

1.10 Topside structure

1.10.1 The minimum scantlings of superstructures and deckhouses are to comply with the requirements of *Pt 4, Ch 6, 9 Superstructures and deckhouses*. Bulwarks and guard rails are to comply with *Pt 4, Ch 6, 10 Bulwarks and other means for the protection of crew and other personnel*.

1.10.2 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures including derricks and flare structures are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with *Pt 3, Ch 8, 2 Structure*. Permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

1.10.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to be designed in accordance with *Pt 4, Ch 3, 4 Structural design loads*, and permissible stress levels are to satisfy the factors of safety given in *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) .

1.10.4 Units with a process plant facility which comply with the requirements of *Pt 3, Ch 8 Process Plant Facility* will be eligible for the assignment of the special features class notation **PPF**.

1.10.5 Units with a drilling plant facility which comply with the requirements of *Pt 3, Ch 7 Drilling Plant Facility* will be eligible for the assignment of the special features class notation **DRILL**.

■ *Section 2*
Sea bed-stabilised units

2.1 General

2.1.1 This Section outlines the structural design requirements of sea bed-stabilised units as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*. Additional requirements for particular unit types related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*. Self-elevating units are to comply with *Pt 4, Ch 4, 3 Self-elevating units*.

2.1.2 Units of this type are generally designed to operate under normal operating environmental conditions and severe storm conditions whilst resting on the sea bed. The design transit condition and design limitations are to be specified by the Owner/designer.

2.1.3 The structural analysis and determination of scantlings is to be on the basis of distribution of loadings and ballast required to satisfy *Pt 4, Ch 4, 2.1 General 2.1.2* and all units are to have adequate reserve of bearing pressure on the support footings, pontoons or mats.

2.1.4 The requirements of *Pt 4, Ch 4, 1 Column-stabilised units* and *Pt 4, Ch 4, 3 Self-elevating units* are to be complied with as applicable to the design of the unit.

2.1.5 The permissible stress levels in all operating modes are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

2.1.6 The minimum local scantlings are to comply with the requirements of *Pt 4, Ch 6 Local Strength*, for column-stabilised units as applicable, but the bottom structure should not be less than required for tank bulkheads in *Pt 4, Ch 6 Local Strength* using the load head h_4 equivalent to the maximum design bearing pressure. In general, bottom primary members supporting shell stiffeners are to be spaced not more than 1,85 m apart and side girders or equivalent are to be spaced 2,2 m apart. The buckling strength of the primary member webs is to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*, *see also Pt 4, Ch 4, 2.4 Corrosion protection*.

2.2 Air gap

2.2.1 For on-bottom modes of operation, the clearance air gap between the underside of the deck structure and the highest predicted design wave crest is to be in accordance with *Pt 4, Ch 4, 3.2 Air gap 3.2.1*. In transit conditions, the air gap is to be in accordance with *Pt 4, Ch 4, 1.2 Air gap*. Calculations, model test results or prototype reports are to be submitted for consideration.

2.3 Operating conditions

2.3.1 Classification will be based upon the Owner's/designer's assumptions in operating the unit and the sea bed conditions. These assumptions are to be recorded in the Operations Manual. It is the responsibility of the Operator to ensure that actual conditions do not impose more severe loadings on the unit.

2.3.2 Procedures and limitations for ballasting and re-floating the unit in order to avoid overstressing the structure by static or dynamic loads are to be clearly defined in the Operations Manual, *see Pt 3, Ch 1, 3 Operations manual*.

2.4 Corrosion protection

2.4.1 The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

2.4.2 The general requirements for corrosion protection are to comply with *Pt 8 CORROSION CONTROL*.

■ *Section 3*
Self-elevating units

3.1 General

3.1.1 This Section outlines the structural design requirements of self-elevating units. Additional requirements for particular unit types related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

3.1.2 A self-elevating unit is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode, *see Pt 1, Ch 2, 2 Definitions, character of classification and class notations*.

3.1.3 Production units are to comply with the requirements of *Pt 3, Ch 3 Production and Storage Units* as applicable.

3.1.4 The structural analysis and determination of primary scantlings are to be on the basis of the distribution of loadings expected in all modes of operation.

3.2 Air gap

3.2.1 When in the elevated position, the unit is to be designed to have a clearance air gap between the underside of the hull structure and the highest predicted design wave crest superimposed on the maximum surge height over the maximum mean astronomical tide. The minimum clearance is not to be less than 1,5 m. Calculations, model test results or prototype reports are to be submitted for consideration.

3.3 Structural design

3.3.1 The structure is to be designed to withstand the static and dynamic loads imposed upon it in transit, installation, re-floating and elevated conditions. All relevant distributions of gravity and variable loads are to be considered, as are stresses due to the overall and local effects, *see Pt 4, Ch 3, 4 Structural design loads*.

3.3.2 The permissible stresses are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength* and the minimum local scantlings of the unit are to comply with *Pt 4, Ch 6 Local Strength*.

3.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in *Pt 4, Ch 5, 1.2 Structural analysis* are to be complied with. The loading conditions applicable to a self-elevating unit are shown in *Pt 4, Ch 4, 3.3 Structural design 3.3.3*.

Table 4.3.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Site installation and re-floating		X		
Operating	X	X	X	X
Survival	X	X	X	X
Transit	X	X	X	X
NOTES				
1. For definition of loading conditions (a) to (d), *see Pt 4, Ch 3, 4.3 Load combinations*.				
2. For loading conditions (c) and (d) as applicable to a self-elevating unit, *see Pt 4, Ch 4, 3.3 Structural design 3.3.4* to *Pt 4, Ch 4, 3.3 Structural design 3.3.6*.				

3.3.4 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*. In transit conditions, collision loads against the hull structure will normally only cause local damage to the hull structure and consequently loading condition (c) in *Pt 4, Ch 4, 3.3 Structural design 3.3.3* need not be investigated from the overall strength aspects. When in the elevated position, accidental damage to the legs is to be considered in the design and the unit is to be capable of absorbing the energy of impact in association with environmental loads corresponding to the appropriate one year storm condition.

3.3.5 In general, for loading condition (c) in *Pt 4, Ch 4, 3.3 Structural design 3.3.3*, the level of impact energy absorbed by the local leg structure is not to be taken less than 2 MJ. If the unit is only to operate in protected waters, as defined in *Pt 1, Ch 2, 2.4 Class notations (hull/structure)*, the level of impact energy absorbed by the local leg structure may be reduced but should not be less than 0,5 MJ. Collision loads will, in general, only cause local damage to one leg, but the possibility of progressive collapse and overturning should be considered in the design calculations which should be submitted for consideration.

3.3.6 The permissible stress levels after credible failures or accidents are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

3.3.7 Fatigue damage due to cyclic loading is to be considered in the design of the legs of the unit for transit and elevated conditions. Fatigue damage is considered accumulative throughout the unit's design life. The extent of the fatigue analysis will be dependent on the mode and area of operations, *see Pt 4, Ch 5, 5 Fatigue design*.

3.4 Hull structure

3.4.1 The hull is to be considered as a complete structure having sufficient strength to resist all induced stresses while in the elevated position and supported by its legs. All fixed and variable loads are to be distributed, by an accepted method of rational analysis, from the various points of application to the supporting legs. The scantlings of the hull are then to be determined consistent with this load distribution.

3.4.2 Due account must be taken of loadings induced in the transit condition from external sea heads, variable deck loads and legs.

3.5 Deckhouses

3.5.1 Deckhouses are to have sufficient strength for their size, function and location. Requirements for scantlings are given in *Pt 4, Ch 6, 9 Superstructures and deckhouses*.

3.5.2 Special consideration is to be given to the scantlings of deckhouses and deck modules which will not be subjected to wave loading in any operating condition such as units which are 'dry-towed' to the operating location.

3.6 Structure in way of jacking or elevating arrangements

3.6.1 Load carrying members in the jackhouses and frames which transmit loads between the legs and the hull are to be designed for the maximum design loads and are to be so arranged that loads transmitted from the legs are properly diffused into the hull structure. The scantlings of jackhouses are not to be less than required for deckhouses in accordance with *Pt 4, Ch 6, 9 Superstructures and deckhouses*.

3.7 Leg wells

3.7.1 The scantlings and arrangements of the boundaries of leg wells are to be specially considered and the structure is to be suitably reinforced in way of leg guides, taking into account the maximum forces imposed on the structure. The minimum scantlings of leg wells are to comply with *Pt 4, Ch 6, 3.3 Self-elevating units*.

3.8 Leg design

3.8.1 Legs may be either shell type or lattice type. Independent footings may be fitted to the legs or legs may be permanently attached to a bottom mat. Shell type legs may be designed as either stiffened or unstiffened shells.

3.8.2 Where legs are fitted with independent footings, proper consideration is to be given to the leg penetration of the sea bed and the end fixity of the leg.

3.8.3 Leg scantlings are to be determined in accordance with a method of rational analysis and calculations submitted for consideration, *see Pt 4, Ch 3, 3 Structural idealisation*.

3.8.4 For lattice legs, the slenderness ratio of the main chord members between joints is not to exceed 40, or two thirds of the slenderness ratio of the leg column as a whole, whichever is the lesser, unless it can be shown that a calculation taking into account beam-column effect, joint rigidity and joint eccentricity justifies a higher figure.

3.9 Unit in the elevated position

3.9.1 When computing leg stresses with the unit in the elevated position, the maximum overturning load and maximum shear load on the unit, using the most adverse combination of applicable variable loadings together with the environmental design loadings, are to be considered with the following criteria:

(a) **Wave forces**: Values of drag coefficient, C_{D} , and inertia coefficient, C_{m} , vary considerably with Reynolds number, R_{n} , and Keulegan-Carpenter number, N_{k} , and are to be carefully chosen to suit the individual circumstances. In calculating the wave forces using acceptable wave theories, values as given in *Pt 4, Ch 4, 3.9 Unit in the elevated position 3.9.1* to *Pt 4, Ch 4, 3.9 Unit in the elevated position 3.9.1* for the hydrodynamic coefficients C_{D} and C_{m} , for non-tubular members of the leg chords may be used essentially in the drag dominated regime with post-critical R_{n} and high N_{k} . Otherwise more detailed information based on tests or published data is to be used.

(i) Cylindrical chord members with protruding racks: Drag coefficient,

$$C_{\mathrm{D}} = C_{\mathrm{d}} + \frac{\left(D_{\mathrm{E}} - D_{\mathrm{C}}\right)}{D_{\mathrm{C}}}(2\sin\theta)$$

For marine fouled members, C_{D} calculated is to be factored by 1,2. Inertia coefficient,

$$C_{\mathrm{M}} = C_{\mathrm{m}}\left(\frac{A_{\mathrm{g}}}{A_{\mathrm{C}}}\right)$$

where

C_{d} = the drag coefficient used for a smooth cylinder member

C_{m} = the inertia coefficient used for a cylinder member

D_{E} = pitch distance of the racks

D_{C} = nominal diameter of the cylindrical part of the member

A_{g} = the cross-sectional area of the member

A_{c} = the cross-sectional area of the cylindrical part of the member

= the angle between the flow direction and the central line of the cross-section along the racks

(ii) Triangular chord members:

Drag coefficient, for smooth triangular members:

C_{D} = 1,6 θ = 0°

C_{D} = 1,4 θ = 45°

C_{D} = 1,8 θ = 90°

C_{D} = 1,7 θ = 135°

C_{D} = 1,3 θ = 180°

For marine fouled members, the C_{D} values are to be factored by 1,2.

Inertia coefficient, C_{m} = 1,4

where

$\boldsymbol{\theta}$ = Relative approach angle of flow, 0° being towards the backplate and to be counted clockwise.

(iii) Other shapes of non-tubular members: C_{D} , C_{m} values should be assessed based on the relevant published data or appropriate tests. The tests should consider possible roughness, Keulegan-Carpenter and Reynolds numbers dependence.

(b) **Dynamics**: Due account of dynamics is to be taken in computing leg stresses when this effect is significant. The following governing aspects are to be included:

(i) The mass and mass distribution of the unit. This includes structural mass, mass of equipment and variable load on board, added mass due to the surrounding water and marine growth, if applicable, etc.
(ii) The global unit structural stiffness. This includes stiffness contributions from the leg to hull connections and the footing interface, if applicable.
(iii) The damping. This includes structural damping, foundation damping and hydrodynamic damping.

(c) **Other considerations**: Other considerations in computing leg stresses include:

(i) Forces and moments due to initial leg inclination and lateral frame deflections of the legs.
(ii) Bending moments at leg/hull connections due to hull sagging under gravity loads.

3.10 Legs in field transit conditions

3.10.1 In field transit conditions within the same geographical area, legs are to be designed for acceleration forces caused by a 6° single amplitude of roll or pitch at the natural period of the unit, plus, 120 per cent of the gravity forces caused by the legs' angle of inclination, unless otherwise verified by appropriate model tests or calculations. The legs are to be investigated for any proposed leg arrangement with respect to vertical position during field transit moves, and the approved positions are to be specified in the Operations Manual. Such investigation is to include strength and stability aspects. Field transit moves may only be undertaken when the predicted weather is such that the anticipated motions of the unit will not exceed the design condition.

3.10.2 The duration of a field transit move may be for a considerable period of time and should be related to the accuracy of weather forecasting in the area concerned. It is recommended that such a move should not normally exceed a twelve hour voyage between protected locations or locations where the unit may be safely elevated. However, during any portion of the move, the unit should not normally to be more than a six hour voyage to a protected location or a location where the unit may be safely elevated. Suitable instructions are to be included in the Operations Manual. Where a special leg position is required for field moves, this position is to be specified in the Operations Manual.

3.11 Legs in ocean transit conditions

3.11.1 In ocean transit conditions involving a move to a new geographical area, legs are to be designed for acceleration and gravity loadings resulting from the motions in the most severe anticipated environmental transit conditions, together with corresponding wind moments. Calculation or model test methods may be used to determine the motions. Alternatively, legs may be designed for the acceleration and gravity forces caused by a design criterion of 20° single amplitude of roll or pitch at a 10 second period. For ocean transit conditions, it may be necessary to reinforce or support the legs, or to remove sections of them. The approved condition is to be included in the Operations Manual.

3.12 Legs during installation conditions

3.12.1 When lowering the legs to the sea bed, the legs are to be designed to withstand the dynamic loads which may be encountered by their unsupported length just prior to touching the sea bed and also to withstand the shock of touching bottom while the unit is afloat and subject to wave motions.

3.12.2 Instructions for lowering the legs are to be clearly indicated in the Operations Manual. The maximum design motions, bottom conditions and sea state while lowering the legs are to be clearly stated. The legs are not to be lowered in conditions which may exceed the design criteria.

3.12.3 For units without bottom mats, all legs are to have the capability of being preloaded to the maximum applicable combined gravity plus overturning load. The approved preload procedure should be included in the Operations Manual.

3.12.4 Consideration is to be given to the loads caused by a sudden penetration of one or more legs during preloading.

3.13 Stability in-place

3.13.1 When the legs are resting on the sea bed, the unit is to have sufficient positive downward gravity loadings on the support footings or mat to withstand the overturning moment of the combined environmental forces from any direction, with a reserve against the loss of positive bearing of any footing or segment of the area, for each design loading condition. The most critical minimum variable load condition is to be considered for each loading direction and in no case is the variable load to be taken greater than 50 per cent of the maximum and using the least favourable location of the centre of gravity.

3.13.2 The safety factor against overturning is to be at least 1,25 with respect to the rotational axis through the centres of the independent footings at the sea bed. For a unit with a mat type footing, the rotational axis is to be taken at the maximum stressed edge of the mat.

3.13.3 For independent footings, the safety factor against sliding at the sea bed is to be related to the soil condition, but in no case is the safety factor to be taken as less than 1,0.

3.14 Sea bed conditions

3.14.1 Classification will be based upon the designer's assumptions regarding the sea bed conditions. These assumptions are to be recorded in the Operations Manual.

3.14.2 Full details of the sea bed at the operating location are to be submitted to LR for review at the design stage. The effects of scouring on bottom mat bearing surfaces and footings is to be considered, *see Pt 4, Ch 4, 3.16 Bottom mat 3.16.3*.

3.15 Foundation fixity

3.15.1 For units with independent legs, foundation fixity should not normally be considered for in-place strength analysis of the upper parts of the leg in way of the lower guides unless justified by proper investigation of the footing and soil conditions.

3.15.2 For in-place analysis, the lower parts of the leg with independent footings are to be designed for a leg moment no less than 50 per cent of the maximum leg moment at the lower guides, together with the associated horizontal and vertical loads.

3.16 Bottom mat

3.16.1 When the legs are attached to a bottom mat, the scantlings of the mat are to be specially considered, but the permissible stress levels are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*. Particular attention is to be given to the attachment, framing and bracing of the mat in order that the loads from the legs are effectively distributed into the mat structure.

3.16.2 Mats and their attachments to the bottom ends of the legs are to be of robust construction to withstand the shock load on touching the sea bed while the unit is afloat and subject to wave motions.

3.16.3 The effects of scouring on the bottom bearing surfaces should be considered by the designer, with a stated design figure for loss of bearing area. The effects of skirt plates, where provided, may be taken into account, *see also Pt 4, Ch 4, 3.14 Sea bed conditions 3.14.1*.

3.16.4 The minimum local scantlings of the mat structures are to comply with *Pt 4, Ch 4, 3.17 Independent footings 3.17.5* and *Pt 4, Ch 4, 3.17 Independent footings 3.17.6*.

3.17 Independent footings

3.17.1 Independent footings are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected, *see also Pt 4, Ch 4, 3.16 Bottom mat 3.16.3*. In general, the primary structure is to be analysed by a three dimensional finite element method.

3.17.2 The complexity of the mathematical model together with the associated element types is to be sufficiently representative of all parts of the primary structure to enable internal stress distributions to be established.

3.17.3 The loading combinations considered are to represent all modes of operation so that the critical design cases are established, and are to include, but not be limited to, the following:

(a) The maximum preload concentrated or distributed over the area of initial contact.
(b) The maximum preload uniformly distributed over the entire bottom area.
(c) The relevant preload distributed over contact areas corresponding to intermediate levels of penetration, as required.
(d) The greatest leg load due to the specified environmental maxima applied over the entire bottom area, with the pressure varying linearly from zero at one end to twice the mean value at the other end.
(e) The distribution in *Pt 4, Ch 4, 3.17 Independent footings 3.17.3* applied in different directions, depending on structural symmetry, to cover all possible wave headings.
(f) Where it is intended to move the unit without the footings being fully retracted, a special analysis of the leg to spudcan connections may be required.

3.17.4 The permissible stresses are to be based on the safety factors for yield and buckling as defined in *Pt 4, Ch 5, 2 Permissible stresses*. The preload cases may be considered as load case (a) in *Pt 4, Ch 5, 2 Permissible stresses* while the loadings associated with the maximum storm cases may be taken as load case (b) in *Pt 4, Ch 5, 2 Permissible stresses*.

3.17.5 The minimum local scantlings of the bottom shell and stiffening and other areas subjected to pressure loading are to be determined from the formulae for tank bulkheads given in *Pt 4, Ch 6, 7 Bulkheads*. The loadhead h_4 should be consistent with the maximum bearing pressure, determined in accordance with *Pt 4, Ch 4, 3.17 Independent footings 3.17.3*, and the wastage allowance of the plating should be not less than 3,5 mm, *see also Pt 4, Ch 4, 3.17 Independent footings 3.17.6*.

3.17.6 Where it is intended to operate at a fixed location for the design life of the unit, the footing/leg structure which is below the mud line or internal areas of the footings which cannot be inspected are to have their structure designed with adequate corrosion margins and protection. The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

3.17.7 When the structure consists of compartments which are not vented freely to the sea, the scantlings of the shell boundaries and stiffening are not to be less than required for tank boundaries in *Pt 4, Ch 6, 7 Bulkheads* using the load head h_4 not less than 1,4 T_0 m, where T_0 is defined in *Pt 4, Ch 1, 5 Definitions*.

3.17.8 Where the legs of the unit are made from steel with extra high tensile strength, special consideration is to be given to the weld procedures for the leg to footing connections. Adequate preheat should be used and the cooling rate should be controlled. Any non-destructive examination of the welds should be carried out after a minimum of 48 hours have elapsed after the completion of welding.

3.18 Lifeboat platforms

3.18.1 When self-elevating units are fitted with cantilevered lifeboat platforms, the strength of the platforms is to comply with *Pt 4, Ch 4, 1.9 Lifeboat platforms*. If the lifeboat platform can be subjected to wave impact forces in transit conditions, the scantlings are to be specially considered and details are to be submitted for consideration by LR.

3.19 Topside structure

3.19.1 General requirements for topside structure are given in *Pt 4, Ch 4, 1.10 Topside structure*.

■ *Section 4* Surface type units

4.1 General

4.1.1 The hull structural design requirements of permanently moored/disconnectable ship units with hull construction in steel engaged in hydrocarbon production and/or storage/offloading at offshore locations are given in *Pt 10 SHIP UNITS*.

4.1.2 Units which operate as shuttle oil tankers will be assigned class in accordance with the Rules for Ships.

4.1.3 The hull structural design requirements of surface type units engaged in drilling and support activities are given in *Pt 4, Ch 4, 4.2 Surface type units for drilling and support activities*.

4.2 Surface type units for drilling and support activities

4.2.1 In general, hull strength, scantlings and arrangements for surface type units are to comply with the relevant requirements of the Rules for Ships as applicable to the service of the unit. For drilling units, the local design heads to be used for the derivation of scantlings for walkways and access areas, work areas and storage areas are not to be less than as shown in *Pt 4, Ch 6, 2.3 Stowage rate and design heads 2.3.2* in *Pt 4, Ch 6 Local Strength*.

4.2.2 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of these Rules, *see also Pt 3, Ch 1 General Requirements for Offshore Units*. Additional requirements related to the design arrangements and function of drilling and production units given in *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures* and *Pt 4, Ch 3 Structural Design* are to be complied with.

4.2.3 **Drilling well/Moonpool**. The hull structure in way of the drilling well is to be suitably strengthened so as to ensure continuity of the required longitudinal strength.

4.2.4 **Structural analysis**. For surface type units, the strength of primary structures of hull compartments and of deck supporting structures, including longitudinal and transverse bulkheads, is to be assessed in accordance with relevant LR *ShipRight SDA Procedures*.

4.2.5 **Fatigue design.** Fatigue damage due to cyclic loading is to be considered. The nature and extent of the fatigue analysis will depend on the mode and area of operation. For details of the fatigue required analyses, *see Pt 4, Ch 5, 5 Fatigue design*.

4.2.6 The scantlings and arrangements of units with a limited number of tanks for bulk storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered. Double hull construction in bulk oil tank storage regions will normally be required, *see also Pt 3, Ch 3 Production and Storage Units*.

4.2.7 Additional requirements related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

Section 5
Buoy units

5.1 General

5.1.1 This Section outlines the structural design requirements of buoys of any shape or form. For deep draught caissons, *see Pt 4, Ch 4, 7 Deep draught caisson units*.

5.1.2 Additional requirements for particular unit types related to the design function of the unit are also given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

5.1.3 The hull structure of buoy units is to be divided into watertight compartments and is to have adequate buoyancy and floating stability in all conditions defined in *Pt 4, Ch 4, 5.6 Structural design 5.6.2*.

5.1.4 Venting arrangements are to be fitted to all tanks or floodable spaces to ensure that air is not trapped in any operating mode, *see Pt 5, Ch 13 Bilge and Ballast Piping Systems*.

5.1.5 Venting of void spaces is normally to comply with *Pt 5, Ch 13 Bilge and Ballast Piping Systems*. Special consideration is to be given to small void spaces.

5.1.6 Any spaces filled with foam or permanent ballast is to be specially considered with regard to the materials and their attachment to the structure.

5.1.7 Hull construction and arrangements of buoys used for the storage of oil in bulk storage tanks are to comply with the requirements of the applicable Coastal State Authority.

5.1.8 The requirements of *Pt 3, Ch 3 Production and Storage Units* and *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures* are to be complied with, as applicable.

5.2 Environmental considerations

5.2.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see Pt 4, Ch 3, 4 Structural design loads*.

5.2.2 A full list of operating and extreme environmental limiting conditions is to be submitted. This is to include the following cases, as applicable, and any other conditions relevant to the system under consideration:

- Extreme survival storm condition.
- Worst environmental conditions in which a ship/unit may remain moored to an installation.
- Worst environmental conditions in which the main operating functions may be carried out (e.g., transfer of product through riser).
- Worst environmental conditions in which a ship/unit may moor on arrival at an off-loading installation.
- Worst environmental conditions in which a disconnectable ship/unit may remain connected.

5.2.3 Environmental factors for mooring systems are to be in accordance with *Pt 3, Ch 10 Positional Mooring Systems*.

5.3 Water depth

5.3.1 The minimum and maximum still water levels at the operating location are to be determined, taking full account of the tidal range, wind and pressure surge effects. Data is to be submitted to show the variation in water depth in way of the installation. This data is to be referenced to a consistent datum and is to include, where relevant, the water depth in way of each anchor or pile, gravity base or foundation, pipeline manifold, and in way of the radius swept by a ship/unit attached to the mooring installation.

5.4 Design environmental conditions

5.4.1 The design is to be considered for the following environmental conditions:

- Extreme storm survival condition.
- Maximum connected condition, *see Pt 4, Ch 4, 5.2 Environmental considerations 5.2.2*.

• Other conditions are to be considered, as defined in *Pt 4, Ch 4, 5.4 Design environmental conditions 5.4.1*.

Table 4.5.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 4	(d) *See* Note 4
Site installation, *see* Note 3	X	X		
Operating, *see* Note 2	X	X	X	X
Survival	X	X	X	X
Transit (loadout), *see* Note 3	X	X		

NOTES

1. For definition of loading conditions (a) to (d), *see Pt 4, Ch 3, 4.3 Load combinations*.

2. For operating conditions, the load cases are to include those defined in *Pt 4, Ch 4, 5.2 Environmental considerations 5.2.2*, as applicable.

3. For loading conditions (a) and (b) for installation and transit conditions, *see Pt 4, Ch 4, 5.6 Structural design 5.6.8*.

4. For loading conditions (c) and (d) as applicable to buoy units, *see Pt 4, Ch 4, 5.6 Structural design 5.6.9*.

5.4.2 **Extreme storm survival condition**. In general, the individual environmental factors (wind, wave and current) are to have an average recurrence period of not less than 100 years. The joint probability of occurrence of extreme values of individual environmental factors is to be taken into account where sufficiently accurate data exists.

5.4.3 **Maximum connected conditions**. The maximum environmental conditions during which disconnectable ships/units will remain connected to the buoy.

5.4.4 Account is also to be taken in the design of the maximum conditions during which particular operational activities or marine operations are intended to be carried out, e.g., production through risers, transfer of product, connection to or disconnection from single-point mooring. Appropriate limits are to be set and defined in the Operations Manual.

5.5 Environmental loadings

5.5.1 The environmental loading on the installation and its motion responses are to be determined and the dynamic effects are to be considered, see *Pt 4, Ch 3, 4 Structural design loads*. Account is to be taken of the following:

(a) Environmental loads and motions are to be established by model testing and suitable calculation methods.
(b) Satisfactory correlation between the calculation method and representative model test results is to be demonstrated.
(c) The possibility of resonant motion is to be fully investigated, taking second order wave forces into account.
(d) In determining environmental loads, account is to be taken of the effect of marine growth. Both an increase in the dimensions of submerged members and the change in surface characteristics are to be considered.
(e) Shallow water effects are to be considered where appropriate.
(f) consideration should be given to performing a full coupled analysis of the buoy, mooring and transfer lines, or risers in the case of deep water buoy units.

5.6 Structural design

5.6.1 The general requirements for structural design are given in *Pt 4, Ch 3 Structural Design* but the additional requirements of this Chapter are to be complied with.

5.6.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit in transit (loadout), site-specific installation, survival and operating conditions. All relevant loads as defined in *Pt 4, Ch 3 Structural Design* are to be considered.

5.6.3 Account is to be taken of slam effects when calculating wave loads in the splash zone.

5.6.4 Local forces from mooring lines and risers are to be included in the analyses for normal operating conditions.

5.6.5 All bearings, guide rollers, etc., forming part of a turntable or other swivel arrangement associated with risers, moorings or pipeline systems on the buoy are to comply with the requirements given in *Pt 3, Ch 13, 6 Mechanical items*.

5.6.6 Permissible stresses due to the overall and local effects are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*. The minimum local scantlings of the unit are to comply with *Pt 4, Ch 6 Local Strength*.

5.6.7 All modes of operation are to be investigated and the relevant design load combinations defined in *Pt 4, Ch 5, 1.2 Structural analysis* are to be complied with. The loading conditions applicable to buoy type units are shown in *Pt 4, Ch 4, 5.4 Design environmental conditions 5.4.1*.

5.6.8 Although buoy units will not be classed during transit (loadout) and during the installation procedure at the operating location, the transit condition and the site-specific installation condition are to be investigated and submitted to LR.

5.6.9 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*. In operating and survival conditions, collision loads against the buoy structure will normally cause only local damage to the structure and consequently loading conditions (c) and (d) in *Pt 4, Ch 4, 5.4 Design environmental conditions 5.4.1* need not be investigated from the overall strength aspects.

5.7 Buoy structure

5.7.1 Buoys are to be designed to withstand the forces and moments resulting from the overall loadings together with the forces and moments due to local loadings, including internal and external pressures.

5.7.2 In general, internal spaces within the buoy are to be designed for the pressure heads defined in *Pt 4, Ch 3, 4.14 Hydrostatic pressures*. The minimum head on shell boundaries is generally not to be less than 6 metres, *see also Pt 4, Ch 4, 7.5 Structural design 7.5.5*. Special consideration will be given to accepting a reduced design head in benign environments where this can be clearly demonstrated.

5.7.3 The minimum scantlings of shell boundaries including moon pools are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons*.

5.7.4 The general requirements for watertight and tank bulkheads are to comply with *Pt 4, Ch 6, 7 Bulkheads*. The scantlings of the boundaries of internal watertight compartments adjacent to the sea which are required for buoyancy and stability to support the structure are to comply with the requirements for tank bulkheads.

5.7.5 The supports for riser systems and mooring systems are to comply with *Pt 4, Ch 6 Local Strength*.

5.8 Topside structure

5.8.1 The scantlings of deck support structures which are designed as a trussed space frame structure are to be determined by analysis. *See also Pt 4, Ch 4, 1.10 Topside structure*.

5.8.2 The minimum scantlings of decks are to comply with *Pt 4, Ch 6, 4 Decks*.

5.8.3 The scantlings of superstructures and deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*.

5.9 Lifeboat platforms

5.9.1 The strength of lifeboat platforms is to be determined in accordance with the requirements of *Pt 4, Ch 4, 1.9 Lifeboat platforms*.

5.10 Fatigue

5.10.1 The structure of buoys and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures are to be assessed for fatigue damage due to cyclic loading.

5.10.2 The general requirements for fatigue design and the factors of safety on fatigue life are to comply with *Pt 4, Ch 5, 5 Fatigue design*.

■ Section 6
Tension-leg units

6.1 General

6.1.1 This Section outlines the structural design requirements of tension-leg units as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*. Additional requirements for particular unit types related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

Note While the requirements of the Rules apply, the recommended practice of API RP 2T "Planning, Designing, and Constructing Tension Leg Platforms", can be used as guidance to address both Rule and complementary requirements.

6.1.2 The requirements of *Pt 4, Ch 4, 1 Column-stabilised units* for semi-submersible units are to be complied with as applicable.

6.1.3 The term 'tension-leg' used in this Section includes all the component parts of the pre-tensioned mooring system in one group and includes the top connections to the unit and the bottom connections to the sea bed foundation. Each unit will have a number of tension legs. Each tension leg may be made up of individual tensioned cables or members which are referred to in this Section as 'tethers'.

6.2 Air gap

6.2.1 Unless the upper hull structure is designed for wave impact, a clearance 'air gap' of 1,5 metres between the underside of the upper hull deck structure and the highest predicted design wave crest is to be maintained during operation on station. Calculations, model test results or prototype reports are to be submitted for consideration.

6.2.2 In cases where the unit is designed without an adequate air gap in accordance with *Pt 4, Ch 4, 6.2 Air gap 6.2.1*, the scantlings of the upper hull deck structure are to be designed for wave impact forces. If the whole hull structure is waterborne, the scantlings are to be specially considered but they are not to be less than would be required for a semi-submersible unit.

6.3 Loading and environmental considerations

6.3.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see Pt 4, Ch 3, 4 Structural design loads*.

6.3.2 The environmental loading on the installation and its motion responses are to be determined and the dynamic effects are to be considered, *see Pt 4, Ch 3, 4 Structural design loads*.

6.3.3 When determining the critical design loadings on tethers, realistic combinations of environmental loadings and unit response are to be taken into account. All loadings and unit motions are to be agreed with LR and the full range of operating draughts are to be considered.

6.3.4 Motions may be determined by a suitable combination of model tests and calculation methods.

6.3.5 The possibility of resonant motions is to be fully investigated, taking a second order wave and wind forces into account. The likelihood of the occurrence of rotational and vertical oscillations is to be particularly considered.

6.3.6 In determining environmental loads, account is to be taken of the effect of marine growth. Both an increase in the dimensions of submerged members and the change in surface characteristics are to be considered.

6.3.7 When carrying out model testing, the test programme and the model test tank facilities are to be to the satisfaction of LR and account is to be taken of the following:

- The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined.
- The tests are to be of sufficient duration to establish low frequency motion behaviour.

6.4 Structural design

6.4.1 The general requirements for structural design are given in *Pt 4, Ch 3 Structural Design*, and the requirements of *Pt 4, Ch 4, 1 Column-stabilised units* for semi-submersible units are to be complied with, except where modified by this Section.

6.4.2 The following effects are to be considered when investigating loading conditions that could lead to fatigue of the structure, tension legs or foundations:

- Variations of combined wave and current to ensure that all damaging stress levels are likely to be included in the analysis.
- Member loading including the effects of varying buoyancy and/or flooding due to wave motions in the splash zone.
- Cyclic loading due to wind and the operation of machinery, where significant.
- Still water loading condition at mean draught.

6.4.3 All modes of operation are to be investigated. The design load cases defined in *API Recommended Practice 2T Third Edition, July 2010 Planning, Designing, and Constructing Tension Leg Platforms* (hereinafter referred to as API RP 2T) are to be complied with. The permissible stresses applicable for these load cases are shown in *Table 4.6.1 Design loading conditions*. In all cases, platform configuration should consider both minimum weight and maximum weight variations.

6.4.4 The minimum local scantlings of the unit are to comply with *Pt 4, Ch 6 Local Strength*.

6.4.5 Although a tension-leg unit will not be classed in the transit condition and during site installation, the transit condition and the site-specific installation condition are to be investigated and submitted to LR.

6.4.6 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*. In operating and survival conditions, collision loads against the hull structure will normally only cause local damage to the structure without heeling, and consequently loading conditions (c) and (d) in *Pt 4, Ch 4, 6.4 Structural design 6.4.6* need not be investigated from the overall strength aspects.

Table 4.6.1 Design loading conditions

API RP 2T Design Load Cases					LR Classification Acceptance Criteria
Design Load Case	Safety Category *see* Note 1	Project Phase	Platform Configuration	Design Environment	
1	A	Construction	Various		*See* Note 2
2	A	Load out	Intact	Calm	*Pt 4, Ch 5, 2.1 General 2.1.1*(a)
3	B	Hull/deck mating	Intact	Site specific	*Pt 4, Ch 5, 2.1 General 2.1.1*(a)
4	B	Tow/transportation	Intact/damaged *see* Note 3	Route *see* Note 4	*Pt 4, Ch 5, 2.1 General 2.1.1*(b)
5	A	Installation	Intact	Installation	*Pt 4, Ch 5, 2.1 General 2.1.1*(a)
6	A	In place	Intact	One-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(a)
7	B	In place	Intact	100-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(b)
8	S	In place	Intact	1000-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(d)
9	B	In place	Damaged - no compensation *see* Note 5	One-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(b)
10	S	In place	Damaged - no compensation *see* Note 5	10-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(d)

11	B	In place	Damaged - compensation *see* Note 5	10-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(b)
12	S	In place	Damaged – compensation *see* Note 5	100-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(d)
13	B	In place	Tendon removed (planned) *see* Note 6	10-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(b)
14	S see Note 7	In place	Tendon removed (planned) *see* Note 6	100-year	*Pt 4, Ch 5, 2.1 General 2.1.1*(d)
15	C	In place	Intact	Site specific *see* Note 8	*Pt 4, Ch 5 Primary Hull Strength*, *Table 5.5.1 Fatigue life factors of safety for structural components*, *Table 5.5.2 Fatigue life factors of safety for anchor line and tether components*
16	Strength Level Event (SLE) *see* Note 9	In place	Intact	Seismic SLE	API 2A WSD for SLE
17	Ductility Level Event (DLE) *see* Note 9	In place	Intact	Seismic DLE	API 2A WSD for DLE

Note 1. The safety categories are defined in API RP 2T as:

Category A - Operational Conditions
Category B - Extreme Conditions
Category S - Survival Conditions
Category C - Fatigue Conditions

Note 2. Construction load cases are not required to be submitted to LR.

Note 3. The damaged condition refers to accidental flooding of at least one watertight compartment.

Note 4. The environmental loads for the delivery voyage are to be calculated at a return period of one year for the intact condition.

Note 5. The damaged condition refers to accidental flooding of at least one watertight hull compartment or tendon. Compensation refers to the use of ballast water to equalise tendon loads.

Note 6. Tendons are designed for the life of the platform. However, tendon disconnection/replacement is to be considered and the platform is to be analysed for removal of one tendon at the most critical location. This condition is a planned maintenance or construction condition, and would include appropriate ballast to maximise performance in this condition.

Note 7. Survival check with tendon removed is against disconnection (not zero tension).

Note 8. The wave scatter diagram used for the calculation of fatigue damage is to contain at least five years of data for the site-specific operating field.

Note 9. Strength Level Event and Ductility Level Event are defined in API 2A-WSD.

6.5 Tension-leg materials

6.5.1 The materials used for tension legs are to be specially considered and the materials used are to comply with the following requirements:

(a) The corrosion protection is to be adequate for the life of the installation.
(b) The materials and their attachments to the structure are to be suitable for their purpose and have adequate fatigue life.
(c) The strength, elasticity and flexibility of the tension legs are to be sufficient to accommodate the design extreme motions of the installation and the dynamic patterns which may be encountered over the whole range of environmental criteria.
(d) The material grades used for tension legs, fittings and attachments to the structure are to have adequate resistance to brittle fracture.

6.5.2 Adequate test data is to be submitted to LR to demonstrate that the materials and fittings used for tension legs will have adequate service life. The design philosophy relating to the life and replacement of tension legs and their fittings is to be clearly stated at the design stage.

6.6 Tension-leg design

6.6.1 When reference to tension legs is made in this sub-Section, the Rules apply to tethers constructed of wire ropes, tubes or any other equivalent section.

6.6.2 The design of tension legs is to comply with API RP 2T in addition to the requirements in this Section.

6.6.3 The leg system is to be fail-safe, in that failure of a single tension-leg member at any time during the life of the installation will not induce stress levels in any other tension-leg member that will produce fatigue failure in that member or its associated fittings in less than one year, assuming average winter conditions, or induce increased accumulated fatigue damage to reduce significantly the overall fatigue life of the system.

6.6.4 In general, each tension leg is to be assembled from tether members of only one type and size. The cross-section of tension leg members may vary in a consistent manner over depth. The fitting of materials having different elastic constants in parallel load-carrying components of a tension leg will not normally be accepted.

6.6.5 All leg tether members forming any one tension leg are to be set to an approximate common tension. Suitable means of adjusting the tensions of the individual components of each leg are to be provided at the upper end of each individual tether, consistent with tension adjustments or tolerances required by design to keep the tendons system within design envelopes.

6.6.6 Means are to be provided for monitoring the tensions in tension-leg components.

6.6.7 The design is to be such that, with suitable ballasting, the minimum tension in any tether can be adjusted to be not less than five per cent of the normal pre-tension. A lesser tension is not normally permitted. Where the Owner requests a relaxation of this requirement, appropriate dynamic analysis is to be carried out to evaluate the tether design.

6.6.8 No end terminal or other fitting associated with the tension legs is to be dependent upon the maintenance of the leg tension to retain it in place.

6.6.9 In general, all leg connections including pins, bearings, locks, etc., are to be arranged by positively activated wedging systems, or otherwise, so that there are no slack fits or non-essential clearances. Screwed and bolted fittings are to be provided with positive locking arrangements.

6.6.10 Arrangements are to be made to prevent kinking and sharp bends in tether members in way of the end fittings. In determining the maximum angles that may be assumed by the leg members in way of end fittings, account is to be taken of the maximum extent of snaking or other dynamic distortions of the legs that could occur in extreme environmental conditions.

6.6.11 The effects of scuffing and wear of tethers within rope guides, bell mouths and other systems due to the movement of leg components caused by motions of the unit are to be taken into account in the design.

6.6.12 The extreme maximum and minimum tether loads, which determine the tether design requirements, are to be calculated.

6.6.13 Tether misalignment where tethers are not completely vertical and parallel are to be taken into account.

6.6.14 The maximum tether load is to be determined at the top of the tether with the unit at its minimum design storm weight and with the highest water level. The calculation is to include the effects of the worst combination of the horizontal centre of gravity position, wave loading, wind and current loading, tether misalignment and dynamic response and platform motions.

6.6.15 The minimum tether load is to be determined at the bottom of the tether with the unit at its maximum design storm weight and at the lowest water level. The calculation is to include the effects of the worst combination of the horizontal centre of gravity position, wave loading, wind and current loadings, tether misalignment and dynamic response, platform motions, catenary effects of tethers and the design margin.

6.6.16 When calculating the minimum tether load, a design margin of five per cent of the nominal pre-tension is to be applied.

6.6.17 The unit with the most unfavourable combination of weight, centre of gravity and buoyancy is to be capable of surviving the worst design damage condition. The requirements for watertight and weathertight integrity are to comply with *Pt 4, Ch 6 Local Strength*.

6.6.18 After flooding of any compartment as required to satisfy *Pt 4, Ch 4, 6.6 Tension-leg design 6.6.17*, the requirements of *Pt 4, Ch 4, 6.6 Tension-leg design 6.6.16* are to be complied with.

6.6.19 Within a period of 12 hours from commencement of any accidental flooding, the loading of the unit is to be adjusted, as necessary, so that the tensions of all tethers at their lower ends remain positive under the most unfavourable environmental conditions which could be expected to occur at the location within a return period of not less than one year. The loading adjustment may be means of deballasting, and/or removal, dumping or horizontal movement of deck loads.

6.7 Tension-leg permissible stresses

6.7.1 The maximum permissible stresses in steel tethers under the worst combination of steady and dynamic loadings are to comply with the following factors of safety based on the tensile yield stress of the material:

(a) With all tethers in a tension-leg group in operation:

- 1,67 for tension.
- 1,43 for combined 'comparative' stress.

(b) With one tether in a tension-leg group non-operational:

- 1,25 for tension.
- 1,11 for 'comparative' stress.

Note For planned inspection, maintenance or replacement carried out under specific environment limits and limited duration the requirement of *Pt 4, Ch 4, 6.7 Tension-leg permissible stresses 6.7.1*(a) should apply while *Pt 4, Ch 4, 6.7 Tension-leg permissible stresses 6.7.1*(b) would address the more general one leg failed damaged load case.

6.8 Tension-leg fatigue design

6.8.1 In the design of tether components, consideration is to be given to the fatigue damage that will result from cyclic stresses. A detailed fatigue analysis is to be performed. The combined axial and bending stress is to be determined by dynamic analysis and is to consider variations around the tether circumference.

6.8.2 Where the tethers are built up of various components such as screwed sections or chain link, the effect of many tether components being connected in series is to be adequately accounted for in the design fatigue life.

6.8.3 The fatigue life of tethers and their end connections and the factors of safety on the calculated design fatigue life are to comply with the requirements of *Pt 4, Ch 5, 5 Fatigue design*.

6.9 Tension-leg foundation design

6.9.1 Tension-leg foundation design requirements are defined in *Pt 3, Ch 14 Foundations*.

6.10 Mechanical components

6.10.1 Essential mechanical components are to be designed such that the components are capable of being condition monitored, repaired and/or replaced. Prototype testing may be required for specialised components or novel design arrangements.

6.11 Monitoring in service

6.11.1 The tether system is to be suitably instrumented and monitored in service to ensure that the system is performing within design limitations.

6.11.2 Provision is to be made to monitor tether top tensions. In addition, it is recommended that the platform mean offset position and the upper and/or lower flexible joint angles of tethers are monitored.

6.12 Tether replacement

6.12.1 Tethers are to be inspected at Periodical Surveys and the Owner/designer is to prepare a planned procedure for inspection, retrieval and replacement of tethers in the event of damage or as part of a planned schedule.

6.12.2 The replacement procedures involved are to be clearly documented with regard to the retrieval method, equipment required and unit operations. The procedures are to be included in the unit's Operations Manual.

6.12.3 It is recommended that an adequate number of spare parts of tethers and mechanical fittings are supplied to the unit and made available during its service life.

■ *Section 7*
Deep draught caisson units

7.1 General

7.1.1 This Section outlines the structural design requirements of deep draught caisson units and similar floating installations as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*, but excluding other unit types defined in this Chapter.

7.1.2 Additional requirements for particular unit types related to the design function of the unit are also given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

7.1.3 The hull of caisson units are to be divided into watertight compartments and have adequate buoyancy and floating stability in all conditions defined in *Pt 4, Ch 4, 7.5 Structural design 7.5.2*.

7.1.4 Watertight compartments which are to be temporarily flooded during site installation or in upending conditions are to have tank bulkhead scantlings as required by *Pt 4, Ch 6, 7 Bulkheads*.

7.1.5 Venting arrangements are to be fitted to all floodable spaces to ensure that air is not trapped in any operating mode or temporary condition.

7.1.6 Any spaces filled with permanent ballast are to be specially considered with regard to the material and its attachment to the structure.

7.1.7 Production and oil storage units are to comply with the requirements of *Pt 3, Ch 3 Production and Storage Units*. Caissons designed for the storage of oil in bulk storage tanks are to comply with the relevant requirements of the National Authority.

7.2 Air gap

7.2.1 In all floating modes of operation, the unit is to be designed to have a clearance air gap between the underside of the top side deck structure and the highest predicted design wave crest. Model test results are to be submitted for consideration.

7.3 Environmental loadings

7.3.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see Pt 4, Ch 3, 4 Structural design loads*.

7.3.2 Although a deep draught caisson unit will not be classed during transit and during the installation procedure at the operating location, the specified limiting design environmental criteria for transit/loadout, upending, and mating conditions for which LR structural approval is required are to be clearly defined and submitted.

7.3.3 Environmental loads and motions are to be established for each mode of operation, including the upending condition, by suitable analysis. Model tests will normally be required.

7.3.4 In determining environmental loads, account is to be taken of the effect of marine growth, *see Pt 4, Ch 3, 4.13 Marine growth*.

7.4 Model testing

7.4.1 The test programme and the model test facilities are to be to LR's satisfaction, *see also Pt 4, Ch 3, 4 Structural design loads*.

7.4.2 The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined. The tests are to be of sufficient duration to establish low frequency motion behaviour.

7.4.3 Model tests are to demonstrate clearly that the air gap as required by *Pt 4, Ch 4, 7.2 Air gap 7.2.1* is maintained in all operating modes.

7.5 Structural design

7.5.1 The general requirements for structural design are given in *Pt 4, Ch 3 Structural Design*, but the additional requirements of this Chapter are to be complied with.

7.5.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit and the structural analysis and determination of primary scantlings are to be on the basis of the distribution of loadings expected in all modes of operation and temporary conditions, including loadout, transportation, upending, lifting and mating, as applicable.

7.5.3 All relevant loads as defined in *Pt 4, Ch 3 Structural Design* are to be considered and special attention is to be made in determining vortex-induced action effects due to wind and sea currents. The arrangement and scantlings of helical plate attachments on the hull, where fitted to keep vortex-induced responses at acceptable levels, are to be specially considered. The shell plating in way of attachments is to be increased.

7.5.4 Local forces from mooring lines and risers are to be included in the analyses for normal operating conditions.

7.5.5 Where units have combined crude oil bulk storage and ballast tanks which are intended to remain full in operating conditions, consideration is to be given to taking the design hydrostatic loading as the difference between external and internal pressures subject to adequate safeguards against accidental loading and agreed survey requirements. The corrosion wastage allowance in such tanks is to be specially considered, *see Pt 4, Ch 4, 7.10 Corrosion protection*.

7.5.6 Permissible stresses due to the overall and local effects are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*. The minimum local scantlings of the unit are to comply with *Pt 4, Ch 6 Local Strength*.

7.5.7 The relevant design load combinations defined in *Pt 4, Ch 4, 2.2 Air gap* are to be complied with. The loading conditions applicable to a caisson unit are shown in *Pt 4, Ch 4, 7.5 Structural design 7.5.7*.

Table 4.7.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 3	(d) *See* Note 3
Site installation,upending/mating, *see* Note 2	X	X		
Operating	X	X	X	X
Survival	X	X	X	X
Transit (loadout), *see* Note 2	X	X		

NOTES

1. For definition of loading conditions (a) to (d), *see Pt 4, Ch 3, 4.3 Load combinations*.

2. For loading conditions (a) and (b) for site installation (upending/mating) and transit (loadout) conditions, *see Pt 4, Ch 4, 7.3 Environmental loadings 7.3.2*.

3. For loading conditions (c) and (d) as applicable to caissons, *see* the general requirements stated in *Pt 4, Ch 4, 1.3 Structural design 1.3.5* to *Pt 4, Ch 4, 1.3 Structural design 1.3.7*, as applicable.

7.5.8 The overall strength of the unit is to be analysed by a three-dimensional finite element method in accordance with *Pt 4, Ch 3, 3 Structural idealisation*.

7.5.9 Where the hull form incorporates a space frame or truss system of braces, the requirements of *Pt 4, Ch 4, 1.7 Main primary bracings* and *Pt 4, Ch 4, 1.8 Bracing joints* are to be complied with.

7.6 Caisson structure

7.6.1 Caissons are to be designed to withstand the forces and moments resulting from the overall loadings together with the forces and moments due to local loadings, including internal and external pressures.

7.6.2 In general, internal spaces within the caisson are to be designed for the pressure heads defined in *Pt 4, Ch 3, 4.14 Hydrostatic pressures*. The minimum head on shell boundaries is not to be less than 6 m, *see also Pt 4, Ch 4, 7.5 Structural design 7.5.5*.

7.6.3 The minimum scantlings of shell boundaries including moon pools are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons*.

7.6.4 The general requirements for watertight and tank bulkheads are to comply with *Pt 4, Ch 6, 7 Bulkheads*. The scantlings of the boundaries of internal watertight compartments adjacent to the sea which are required for buoyancy and stability to support the structure are to comply with the requirements for tank bulkheads, *see also Pt 4, Ch 4, 7.10 Corrosion protection*.

7.6.5 Internal caisson structure supporting main bracings is in general not to be of a lesser strength than the bracing itself.

7.6.6 The supports for riser systems and mooring systems are to comply with *Pt 4, Ch 6 Local Strength*.

7.7 Topside structure

7.7.1 The scantlings of deck support structures which are designed as a trussed space frame structure are to be determined by analysis. The requirements of *Pt 4, Ch 4, 7.5 Structural design 7.5.9* are to be complied with.

7.7.2 The minimum scantlings of decks are to comply with *Pt 4, Ch 6, 4 Decks*.

7.7.3 The scantlings of superstructures and deckhouses are to comply with *Pt 4, Ch 6, 9 Superstructures and deckhouses*.

7.8 Lifeboat platforms

7.8.1 The strength of lifeboat platforms is to be determined in accordance with the requirements of *Pt 4, Ch 4, 1.9 Lifeboat platforms*.

7.9 Fatigue

7.9.1 The structure of deep draught caissons and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures is to be assessed for fatigue damage due to cyclic loading.

7.9.2 The general requirements for fatigue design and the factors of safety on fatigue life are to comply with *Pt 4, Ch 5, 5 Fatigue design*.

7.10 Corrosion protection

7.10.1 The general requirements for corrosion protection are to comply with *Pt 8 CORROSION CONTROL*.

7.10.2 In tanks referred to in *Pt 4, Ch 4, 7.5 Structural design 7.5.5*, due to design operating procedures or in areas where it is not considered practicable to inspect internal spaces or replace corrosion protection systems, the structure is to be designed with adequate corrosion margins and protection for the service life of the caisson. The corrosion wastage allowance and protection of all structural components are to be to the satisfaction of LR and agreed at the design stage.

7.10.3 Where practicable, suitable inspection coupons or other inspection aids are to be incorporated into the structure so that the degree of corrosion in inaccessible spaces can be monitored during Periodical Surveys required by*Pt 1 REGULATIONS*.

■ *Section 1*
General requirements

1.1 General

1.1.1 This Section defines the overall strength requirements of the unit and the permissible stresses in all operating modes.

1.1.2 The design loads are to be in accordance with *Pt 4, Ch 3, 4 Structural design loads* and the design conditions are to be based on the most unfavourable combinations of gravity loads, functional loads, environmental loads and accidental loads.

1.1.3 Specific requirements for structural unit types are also defined in *Pt 4, Ch 4 Structural Unit Types*.

1.1.4 The local strength of the unit is to comply with the requirements of *Pt 4, Ch 6 Local Strength*.

1.1.5 The limiting design environmental and operational conditions for each mode of operation is to be defined by the Owner/designer and included in the Operations Manual, *see Pt 3, Ch 1, 3 Operations manual*.

1.2 Structural analysis

1.2.1 A structural analysis of the primary structure of the unit is to be carried out in accordance with the requirements of *Pt 4, Ch 3 Structural Design* and the resultant stresses determined.

1.2.2 The loading conditions are to represent all modes of operation and the critical design cases obtained.

1.2.3 The structure is to be analysed for the relevant load combinations given in *Pt 4, Ch 3, 4.3 Load combinations*.

1.2.4 For the combined load cases applicable to all unit types, *see also Pt 4, Ch 4 Structural Unit Types*.

1.2.5 The permissible stress levels relevant to the combined load cases defined in *Pt 4, Ch 5, 1.2 Structural analysis 1.2.3* are to be in accordance with *Pt 4, Ch 5, 2 Permissible stresses*.

1.2.6 Special consideration is to be given to structures subjected to large deformations.

1.3 Primary structure

1.3.1 Local stresses, including those due to circumferential loading on tubular members, are to be added to the primary stresses to determine total stress levels.

1.3.2 The scantlings are to be determined on the basis of criteria which combine, in a rational manner, the individual stress components acting on the various structural elements of the unit. The stresses are to be determined with corrosion allowance deducted from the gross scantlings in accordance with *Table 3.7.2 Corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment* in *Pt 4, Ch 3 Structural Design*, *see also Pt 3, Ch 1, 5 Corrosion control*.

1.3.3 The critical buckling stress of structural elements is to be considered in relation to the computed stresses, *see Pt 4, Ch 5, 3 Buckling strength of plates and stiffeners* and *Pt 4, Ch 5, 4 Buckling strength of primary members*.

1.3.4 Fatigue damage due to cyclic loading is to be considered in the design of the unit in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

1.3.5 When computing bending stresses, the effective flange areas are to be determined in accordance with 'effective width', concepts derived from accepted shear lag theories and plate buckling considerations.

1.3.6 Where appropriate, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading, and the resulting bending moments superimposed on the bending moments computed for other types of loadings.

1.3.7 When computing shear stresses in bulkheads, plate girder webs or hull side plating, only the effective shear area of the plate or web is to be considered. For girders, the total depth of the girder may be considered as the web depth.

1.3.8 Members of lattice type structures may be designed in accordance with a recognised Code as defined in *Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*.

1.4 Connections and details

1.4.1 Special consideration is to be given to structural continuity and connections of critical components of the primary and special structure, such as the following:

- Bracing intersections and end connections.
- Columns to lower and upper hulls.
- Jackhouses to deck.
- Legs to mat or footings.
- Turret areas.
- Yokes and mooring arms.
- Mooring line attachments.
- Swivel stack supports.

1.4.2 Critical joints which depend upon the transmission of tensile stresses through the thickness perpendicular to the plate surface of one of the members are to be avoided wherever possible. Where the stresses perpendicular to the plate surface exceed 50 per cent of the Rule permissible stress and the thickness exceeds 15,0 mm, plate material with suitable through thickness properties as required by *Ch 3, 8 Plates with specified through thickness properties* of the *Rules for the Manufacture, Testing and Certification of Materials* is to be used.

1.4.3 Welding and structural details are to be in accordance with *Pt 4, Ch 8 Welding and Structural Details*.

1.5 Stress concentration

1.5.1 The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of load-carrying elements.

■ *Section 2*
Permissible stresses

2.1 General

2.1.1 For the combined load cases, as defined in *Pt 4, Ch 3, 4.3 Load combinations*, the maximum permissible stresses of steel structural members are to be based on factors of safety indicated in *Table 5.2.1 Factors of safety for the combined load cases*.

Table 5.2.1 Factors of safety for the combined load cases

Permissible stresses for:	Load case (a)	Load case (b)	Load case (c)	Load case (d)
Shear (based on the tensile yield stress)	2.5	1.89	1.89	1.72

Shear buckling (based on the shear buckling stress)	1.67	1.25	1.25	1.0
Tension and bending (based on the tensile yield stress)	1.67	1.25	1.25	1.0
Compression (based on the lesser of the least bucking stress or the yield stress)	1.67	1.25	1.25	1.0
Combined "comparative" stress (based on the tensile yield stress)	1.43	1.11	1.11	1.0

2.1.2 For plated structures, the combined 'comparative' stress is to be determined where necessary from the formula:

$$\sigma_{cc} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where σ_x and σ_y are the combined axial and bending stresses in the X and Y directions respectively, τ is the combined shear stress due to torsion and/or bending in the X-Y plane.

2.1.3 When finite element methods are used to verify scantlings, special consideration will be given to areas of the structure where localised peak stresses occur.

2.1.4 Non linear and plastic design methods may be used for verifying the local structure in load cases (c) and (d), as defined in *Pt 4, Ch 3, 4.3 Load combinations*. Local yielding and permanent deformation can be accepted; however, the structural arrangements must prevent progressive collapse.

2.1.5 The buckling strengths of plates and stiffeners are to comply with *Pt 4, Ch 5, 3 Buckling strength of plates and stiffeners*.

2.1.6 The buckling strength for individual primary members subjected to axial compression and combined axial compression and bending is to be in accordance with *Pt 4, Ch 5, 4 Buckling strength of primary members*.

2.1.7 Permissible stress levels for lattice type structures are to be determined as required by *Pt 4, Ch 5, 1.3 Primary structure 1.3.8*.

2.1.8 Permissible stresses in materials other than steel are to be specially considered.

■ *Section 3*
Buckling strength of plates and stiffeners

3.1 Application

3.1.1 The requirements of this Section apply to plate panels, and attached stiffeners subject to overall hull structure compression and shear stresses. The maximum design values computed are to be determined in accordance with *Pt 4, Ch 5, 1.2 Structural analysis*.

3.1.2 For states of stress which cannot be defined by one single reference stress, the buckling characteristics are to be based on recognised interaction formulae.

3.1.3 LR's ShipRight buckling modules may be used for the buckling assessment of flat rectangular plate panels by direct calculation.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

E = modulus of elasticity, in N/mm$_2$ (kgf/mm^2)
= 206 000 N/mm^2 (21 000 kgf/mm^2) for steel

σ_{o} = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

σ_{CRB} = critical buckling stress in compression, in N/mm^2 (kgf/mm^2), corrected for yielding effects

σ_{E} = elastic critical buckling stress in compression, in N/mm^2 (kgf/mm^2)

τ_{CRB} = critical buckling stress in shear, in N/mm^2 (kgf/mm^2), corrected for yielding effects

τ_{E} = elastic critical buckling stress in shear, in N/mm^2 (kgf/mm^2)

$\tau_{\text{o}} = \dfrac{\sigma_{\text{o}}}{\sqrt{3}}$

3.3 Elastic critical buckling stress

3.3.1 The elastic critical buckling stress of plating and stiffeners is to be determined in accordance with an agreed Code or Standard or according to *Pt 3, Ch 4, 7.4 Design stress 7.4.1* and *Pt 3, Ch 4, 7.5 Scantling criteria 7.5.3* in *Pt 3, Ch 4, 7 Hull buckling strength*, of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

3.4 Scantling criteria

3.4.1 The critical buckling stress in compression, corrected for yielding effects, σ_{CRB} , of plate panels and stiffeners, as derived from *Pt 3, Ch 4, 7.4 Design stress 7.4.1* and *Pt 3, Ch 4, 7.5 Scantling criteria 7.5.3* in *Pt 3, Ch 4, 7 Hull buckling strength* of the Rules for Ships, is to satisfy the following:

$\sigma_{\text{CRB}} \geq F_{\text{SC}}\ \sigma_{\text{A}}$

where

F_{SC} = factor of safety for compression in accordance with *Pt 4, Ch 5, 2.1 General 2.1.1* for the appropriate load case.

3.4.2 The critical buckling stress in shear, corrected for yielding effects, τ_{CRB} , of plate panels as derived from *Pt 3, Ch 4, 7.4 Design stress 7.4.1* (c) in *Pt 3, Ch 4, 7 Hull buckling strength* of the Rules for Ships, is to satisfy the following:

$\tau_{\text{CRB}} \geq F_{\text{SS}}\ \tau_{\text{A}}$

where

F_{SS} = factor of safety for shear buckling in accordance with *Pt 4, Ch 5, 2.1 General 2.1.1* for the appropriate load case.

3.4.3 Buckling criteria are to be determined for plating and plate and stiffener combinations, including (but not limited to):

- Flat bar stiffeners.
- Bulb plate stiffeners.
- Rolled angles.
- Built-up profiles.
- Floors or deep girders.

3.4.4 All appropriate buckling modes are to be investigated, including:

- Column buckling.

- Torsional buckling.
- Web and flange buckling.

3.4.5 The stresses are to be determined with corrosion allowance deducted from the gross scantlings in accordance with *Table 3.7.2 Corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment* in *Pt 4, Ch 3 Structural Design*

■ *Section 4* Buckling strength of primary members

4.1 Application

4.1.1 The requirements of this Section are applicable to individual primary structural members which are subjected to axial compression or combined axial compression and bending due to overall loading.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ_{o} ,*E* as defined in *Pt 4, Ch 5, 3.2 Symbols 3.2.1*

σ_{A} = computed axial compressive stress, in N/mm^2 (kgf/mm^2)

σ_{B} = computed compressive stress due to bending, in N/mm^2 (kgf/mm^2)

F_{A} = factor of safety for compression, in accordance with*Pt 4, Ch 5, 2.1 General 2.1.1*

F_{B} = factor of safety for bending, in accordance with *Pt 4, Ch 5, 2.1 General 2.1.1*

F_{C} = factor of safety for overall member buckling, as determined from *Pt 4, Ch 5, 4.4 Scantling criteria 4.4.1*

σ_{CRB} = critical overall member buckling stress, in N/mm^2 (kgf/mm^2), as determined from *Pt 4, Ch 5, 4.4 Scantling criteria 4.4.1*

σ_{C} = local member critical buckling stress, in N/mm^2 (kgf/mm^2)

σ_{PA} = permissible axial compressive stress, in N/mm^2 (kgf/mm^2)

= $\dfrac{\sigma_{\mathrm{o}}}{F_{\mathrm{A}}}$ or $\dfrac{\sigma_{\mathrm{c}}}{\mathrm{F_A}}$ or $\dfrac{\sigma_{\mathrm{CRB}}}{\mathrm{F_C}}$ whichever is the lesser

σ_{PB} = permissible compressive stress due to bending, in N/mm^2 (kgf/mm^2)

= $\dfrac{\sigma_{\mathrm{o}}}{F_{\mathrm{B}}}$ or $\dfrac{\sigma_{\mathrm{c}}}{\mathrm{F_B}}$ whichever is the lesser

D = mean diameter of cylindrical shell, in mm

t = thickness of cylindrical shell, in mm.

4.3 Elastic critical buckling stress

4.3.1 Where the elastic critical buckling stress exceeds 50 per cent of the specified minimum yield stress of the material, the calculated critical buckling stresses are to be corrected for yielding effects and are given by:

$\sigma_C = \sigma_o(1 - \sigma_o/4\sigma_E)$ N/mm^2 (kgf/mm^2) in compression.

4.4 Scantling criteria

4.4.1 Individual members are to be investigated for overall critical buckling in accordance with an agreed Code or Standard or *Pt 4, Ch 5, 4.4 Scantling criteria 4.4.1* and *Pt 4, Ch 5, 4.4 Scantling criteria 4.4.1* and also for local buckling.

Table 5.4.1 Overall member critical buckling stress

Condition	Member critical buckling stress σ_{CRB}, N/mm^2 (kgf/mm^2)
(a) When $\lambda < \sqrt{\eta}$	$\sigma_o - \dfrac{\sigma_o^2 \lambda^2}{4\pi^2 E}$
(b) When $\lambda \geq \sqrt{\eta}$	$\dfrac{\pi^2 E}{\lambda^2}$
Symbols and parameters	
σ_o, E as defined in *Pt 4, Ch 5, 3.2 Symbols 3.2.1* l = unsupported length of member, in metres K = effective length factor to be generally taken as unity but will be specially considered in association with end conditions $l_e = Kl$ = unsupported effective length of member, in metres r = least radius of gyration of member cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I}{A}}$ mm A = cross-sectional area of member, in cm^2 I = least moment of inertia of member cross-section, in cm^4 λ = slenderness ratio and may be taken as: $\lambda = \dfrac{1000 l_e}{r}$ $\eta = \dfrac{2\pi^2 E}{\sigma_o}$	

Table 5.4.2 Factors of safety for overall member buckling

Condition	Factor of safety, F_c
(1) For case (a) as defined in *Pt 4, Ch 5, 2.1 General 2.1.1*:	
(a) When $\lambda < \sqrt{\eta}$	$1,67 + \dfrac{0,25\,\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,92
(2) For cases (b) and (c) as defined in *Pt 4, Ch 5, 2.1 General 2.1.1*:	
(a) When $\lambda < \sqrt{\eta}$	$1,25 + \dfrac{0,19\,\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,44
(3) For case (d) as defined in *Pt 4, Ch 5, 2.1 General 2.1.1*:	

(a) When $\lambda < \sqrt{\eta}$	$1{,}0 + \frac{0{,}15\,\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,15
Symbols and parameters	
F_C as defined in *Pt 4, Ch 5, 4.2 Symbols 4.2.1* λ and η as defined in *Pt 4, Ch 5, 4.4 Scantling criteria 4.4.1*	

4.4.2 The local buckling of cylindrical shells, either unstiffened or ring-stiffened, is to be investigated if the proportions of the shell conform to the following:

$$\frac{D}{t} > \frac{E}{9\,\sigma_o}$$

4.4.3 When individual primary structural members are subjected to axial compression or combined axial compression and bending, the computed design stresses are to satisfy the following requirement:

$$\frac{\sigma_A}{\sigma_{PA}} + \frac{\sigma_B}{\sigma_{PB}} \leq 1{,}0$$

■ *Section 5*
Fatigue design

5.1 General

5.1.1 Fatigue damage due to cyclic loading is to be considered in the design of all unit types. The extent of the fatigue analysis will be dependent on the mode and area of operation.

5.1.2 Where any unit is intended to operate at one location for an extended period of time, a rigorous fatigue analysis is to be performed using the long-term prediction of environment for that area of operation with the unit at the intended orientation. Due allowance is to be made of any previous operational history of the unit.

5.1.3 The two basic methods of fatigue analysis available are Deterministic Fatigue Analysis and Spectral Fatigue Analysis. Both are acceptable to LR.

5.1.4 Factors which influence fatigue endurance and should be accounted for in the design calculations include:

- Loading spectrum.
- Detail structural design.
- Fabrication and tolerances.
- Corrosion.
- Dynamic amplification.

5.1.5 The following important sources of cyclic loading should be considered in the design:

- Waves (including those which cause slamming and variable-buoyancy effects).
- Wind (especially when vortex shedding is induced, e.g., on slender members).
- Currents (where these influence the forces generated by waves and/or induced vortex shedding).
- Mechanical vibration (e.g., caused by operation of machinery).

5.1.6 Where a fine mesh finite element analysis is carried out to determine local geometric stress concentration factors, selection of associated S-N curves will be specially considered. Account is to be taken of fatigue stress direction relative to the weld. In general, the element mesh size adjacent to the weld detail under consideration is to be of the order of the local plate thickness. Mesh arrangement and analysis methodology are to be agreed with LR.

5.1.7 The stresses are to be determined with corrosion allowance deducted from the gross scantlings in accordance with *Table 3.7.2 Corrosion allowance to be deducted from the gross scantlings prior to the compliance assessment* in *Pt 4, Ch 3 Structural Design*, *see also Pt 3, Ch 1, 5 Corrosion control*.

5.2 Fatigue life assessment

5.2.1 Fatigue life assessment of all relevant structural elements is required to demonstrate that structural connections have a fatigue endurance consistent with the planned life of the unit and compliance with the minimum requirements. The following structural elements are to be included:

(a) Column-stabilised and tension-leg units:

- Bracing structure.
- Bracing connections to lower hulls, columns and decks.
- Column connections to lower hulls.
- Column connections to deck.
- Mooring structure and associated hull structure integration.
- General structural discontinuities.

(b) Surface type units:

- Hull longitudinal stiffener connections to transverse frames and bulkheads.
- Toe area of main structural brackets.
- Hopper knuckle connections.
- Main openings in the hull envelope.
- Mooring structure and associated hull structure integration.
- General structural discontinuities in the primary hull structure.

(c) Self-elevating units:

- Lattice legs and connections to footings.
- Leg support structure.
- Raw water towers.

(d) Other unit types:

- Special consideration will be given to the hull structure of other unit types on the basis of this Section.

(e) General: Hull, deck and supporting structure in way of topside facilities, e.g:

- Module support.
- Process plant support stools.
- Crane pedestal.
- Flare structures.
- Offloading station.
- Drilling derrick and substructures.

(f) General: Other structures subjected to significant cyclic loading.

5.2.2 Fatigue life is normally governed by the fatigue behaviour of welded joints, including both main and attachment welds. Structure is to be detailed and constructed to ensure that stress concentrations are kept to a minimum and that, where possible, components may deform without introducing secondary effects due to local restraints.

5.2.3 The minimum design fatigue life of a unit is to be specified by the Owner, but is not to be less than 25 years, unless agreed otherwise by LR. *See also Pt 10 SHIP UNITS* for ship units.

5.3 Fatigue damage calculations

5.3.1 The fatigue damage calculations are to be based on the long-term distribution of the applied stress ranges. A sufficient number of draughts and directions are to be included.

5.3.2 An appropriate wave spectrum is to be used and representative percentages of the total cumulative spectrum included for each direction under consideration. When using a limited number of directions, account is to be taken of symmetry within the structure.

5.3.3 Cumulative damage may be calculated by Miner's summation:

$$\frac{\Sigma_s}{i=1}\left[\frac{n_\mathrm{i}}{N_\mathrm{i}}\right] \le \frac{1,0}{F_\mathrm{s}}$$

where

s = number of stress range blocks

n_{i} = actual number of cycles for stress range block number 'i'

N_{i} = corresponding number of cycles obtained from the relevant S-N curve for the detail under consideration

F_{s} = fatigue factor of safety from *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2* or *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2*.

5.3.4 Cumulative damage for individual components is to take into account the degree of redundancy, accessibility of the structure and also the consequence of failure.

5.3.5 Fatigue life estimation is normally to be based on the Miner's summation method given in *Pt 4, Ch 5, 5.3 Fatigue damage calculations 5.3.3*, but consideration will be given to the use of an appropriate fracture mechanics assessment.

5.3.6 Where wave scatter diagrams are used for the calculation of fatigue damage for mobile offshore units and transit voyages of floating offshore installations at a fixed location, the scatter diagram is to contain at least one year of data

5.4 Joint classifications and S-N curves

5.4.1 Acceptable joint classification and S-N curves for structural details are contained in *Pt 4, Ch 12 Appendix A Fatigue – S-N Curves, Joint Classification and Stress Concentration Factors*.

5.4.2 Consideration will be given to the use of alternative methods; detailed proposals are to be submitted and agreed with LR.

Table 5.5.1 Fatigue life factors of safety for structural components

Inspectable/repairable	Fatigue life factor	
	Consequence of failure	
	Non-substantial	Substantial *See* Notes 1 and 4
Yes, dry *See* Notes 2 and 5	1	2
Yes, wet *See* Note 3	2	4
No	3	10

NOTES

1. Substantial consequences of failure include, *inter alia*, loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking. In assessing consequences, account should be taken of the potential for progressive failure. This factor will be applicable for bottom structure of oil storage tanks of single bottomed units and side structures of oil storage tanks of single sided units. This factor will be applicable for supports for risers, umbilicals and caissons; stools for safety critical topside modules; crane pedestals and crane boom rests; supports for topside structures including drilling plants, process plants, flare towers, pipe-lay towers and derricks; supports for helidecks; supports for lifeboat platforms; mooring attachments; supports for thrusters; supports for main engines; supports for liquefied natural gas tanks and supports for offloading stations.

2. Includes internal and external structural elements and connections which can be subjected to dry inspection and repair.

3. Includes external structural elements and connections situated below the minimum operating draught of the unit or structure which can only be inspected during in-water surveys but dry repairs could be carried out subject to special arrangements being provided.

4. The use of fatigue life factors for non-substantial consequences of failure will be specially considered provided it can be demonstrated that there is adequate structural redundancy after fatigue failure. To demonstrate redundancy the structure is to comply with loading condition (d) in *Pt 4, Ch 3, 4.3 Load combinations 4.3.1*. The environmental loads for this loading condition are to be taken as the same as determined for loading condition (b) in *Pt 4, Ch 3, 4.3 Load combinations 4.3.1*.

5. Connections that are covered by passive fire protection are to be considered as non-inspectable unless it can be confirmed that the passive fire protection is to be removed for each inspection.

Table 5.5.2 Fatigue life factors of safety for anchor line and tether components

Replaceable	Inspectable for fatigue (damage/cracks etc.)	Fatigue life factor
Yes	Dry	3
Yes	Wet	5
No	No	10
NOTES		
1.	Anchor line components include chains, steel wire ropes, synthetic fibre ropes and associated fittings such as shackles, connecting links, rope sockets and terminations. Tether components include tubular or rod tendon elements, connectors etc.	
2.	Inspection in the context of this table, assumes the ability to detect onset of fatigue cracks, for example through periodical NDE and dimensional measurements on the component to capture any rate of wear or corrosion significantly higher than assumed in design. Such inspection should be carried out in accordance with an approved Inspection, Monitoring, Maintenance and Repair plan. Inspectable dry: Includes mooring line components and connections which can be subjected to dry inspection and repair, thus mainly on the deck or not subject to water splash or spray. Inspectable wet: Includes mooring lines components and connections situated in the splash zone and may be occasionally or at all times wet during service but can be retrieved for periodical inspection in dry conditions. Replaceable: A mooring line component may be considered replaceable when such timely replacement is shown practical subject to special arrangements within a specific time frame, all documented in an approved Inspection, Monitoring and Maintenance and Repair plan.	
3.	It is recommended that the main mooring line components above the seabed be designed for potential replacement offshore. For the component to be considered replaceable, the Inspection, Monitoring and Maintenance and Repair plan or the Mooring Line Failure Response procedure shall report a detailed replacement procedure and consistent sparing policy to enable prompt replacement of two same components i.e. demonstrate that replacement is practicable.	

4.	In the vicinity of points of constraint (e.g. top chain at stopper) tension, In and Out of Plane Bending and other cyclic loading shall be accounted for as applicable to the specific design. The methodology, selected fatigue damage curves, associated factors of safety shall be demonstrated to provide conservative safety margins at least consistent with that of the same component under cyclic tension load only, based on recognised T-T factor of safety of 10. The supporting documents shall be submitted to LR for review and acceptance. Higher factors of safety will apply when specified by the Owner (in the design Basis).
5.	The safety factor of attachment point and support equipment (e.g. chain-stoppers, bending shoes, pivots, fairleads etc.) shall be consistent with that of the mooring line it supports.

5.4.3 Full penetration welds are normally to be used for all nodal joints (i.e., tubular brace to chord connections). For full penetration welded joints, fatigue cracking would usually be located at the weld toe. However, if partial penetration welds have to be used where weld throat failure is a possibility, fatigue should be assessed using the 'W' curve and a shear stress estimated at the weld root.

5.4.4 For nodal joints, the stress range to be used in the fatigue analysis is the hot spot stress range at the weld toe. For any particular type of loading (e.g., axial loading) this stress range is the product of the nominal stress range in the brace and the appropriate stress concentration factor (SCF).

5.4.5 The hot spot stress is defined as the greatest value around the brace/chord intersection of the extrapolation to the weld toe of the geometric stress distribution near the weld toe. This hot spot stress incorporates the effects of overall joint geometry (i.e., the relative sizes of brace and chord) but omits the stress-concentrating influence of the weld itself which results in a local stress distribution. Hence, the hot spot stress is considerably lower than the peak stress but provides a consistent definition of stress range for the design S-N curve (curve 'T' shown in *Pt 4, Ch 12 Appendix A Fatigue – S-N Curves, Joint Classification and Stress Concentration Factors*). Stress ranges both for the brace and chord sides are to be considered in any fatigue assessment.

5.4.6 For all other types of joint (e.g., welded stiffeners or attachments, including those at nodal joints) the joint classifications and corresponding S-N curves are to take into account the local stress concentrations created by the joints themselves and by the weld profile. The relevant stress range is then the nominal stress range which is to include any local bending adjacent to the weld under consideration. However, if the joint is also situated in a region of stress concentration resulting from the gross shape of the structure, this is to be taken into account.

5.4.7 In load-carrying partial penetration or fillet-welded joints, where cracking could occur in the weld throat, the relevant stress range is the maximum range of shear stress in the weld metal. For details which are particularly fatigue-sensitive, where failure could occur through the weld, full penetration welding is normally to be used.

5.4.8 Geometric stress concentrations may be determined from experimental tests, appropriate references, semi-empirical or parametric formulae or analytical methods (e.g., finite elements analysis). *See also Pt 4, Ch 12 Appendix A Fatigue – S-N Curves, Joint Classification and Stress Concentration Factors*.

5.4.9 Normal fabrication tolerances according to good workmanship standards as given by the Rules are considered to be implicitly accounted for in the S-N curves.

5.5 Cast or forged steel

5.5.1 Fatigue life calculations for cast or forged steel structural components are to include details of the fatigue endurance curve for the material, taking account of the particular environment, mean stress and the existence of casting defects, and the derivation of any stress concentration factors.

5.6 Factors of safety on fatigue life

5.6.1 The minimum factors of safety on the calculated fatigue life of structural components are to be in accordance with *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2*. For mooring systems, *see Pt 4, Ch 5, 5.6 Factors of safety on fatigue life 5.6.2*.

5.6.2 The minimum factors of safety on the calculated fatigue life of anchor lines and tether components of mooring systems are to be in accordance with *Pt 4, Ch 5, 5.4 Joint classifications and S-N curves 5.4.2*.

■ *Section 1* General requirements

1.1 General

1.1.1 All parts of the structure are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected. Permissible stresses for direct calculation methods are to comply with the requirements of *Pt 4, Ch 5 Primary Hull Strength*.

1.1.2 The local effects of the loadings listed in *Pt 4, Ch 3, 4 Structural design loads* are to be considered and all parts of the structure are to be examined individually as necessary, and the calculations submitted. The minimum Rule scantlings of all structures are also to comply with the requirements of this Chapter, as applicable. These requirements are based on a net scantlings approach, *see Pt 4, Ch 3, 7 Corrosion additions* where the corrosion addition for structural elements is to be derived independently of the net scantling requirements, and is to consider the service life, operating environment and the inspection regime of the Owner/operator, as agreed with LR.

1.1.3 The design heads for local strength of column-stabilised, sea bed-stabilised and self-elevating units are to be in accordance with *Pt 4, Ch 6, 2 Design heads*.

1.1.4 The local strength of ship units is to comply with *Pt 10 SHIP UNITS*. The local strength of other surface type units is to comply with *Pt 4, Ch 4, 4 Surface type units*.

1.1.5 The scantlings of machinery seatings are to be specially considered. On self-propelled units, full details of power, and RPM, etc. are to be submitted.

1.1.6 The connections to anchor points as defined in *Pt 3, Ch 10, 10 Fairleads and cable stoppers* and the structure in way of fairleads, stoppers, winches, etc. (*seePt 3, Ch 10, 10 Fairleads and cable stoppers* and *Pt 3, Ch 10, 11 Anchor winches and windlasses*) forming part of anchoring or positional mooring systems are to be designed for a working load equal to the breaking strength of the mooring or anchoring lines main component it connects to. Permissible stresses are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*. Special consideration will be given to grouped line redundant positional mooring systems.

Note a) Exposure of the support structure to breaking loads is most likely to occur in an accidental scenario. Such scenarios may overload the mooring line component closest to the anchor (attachment or connection) point to Offshore Unit, short cutting any weaker component in the mooring line.

Note b) The breaking strength referred to here is the mean breaking strength plus two standard deviations (as new from test data) of the component considered (e.g. steel wire rope, chain or fibre rope) directly acting on or closest in the load path to

the structure under consideration and is generally not to be taken lower than 110 per cent of the nominal minimum break strength of the component.

1.1.7 The mooring equipment between the unit and visiting vessels including supply boats and shuttle tankers is to be designed for a working load equal to the breaking strength of the mooring line. The supporting structure on the unit for these moorings is to be designed for a working load equal to the breaking strength of the mooring line. Permissible stresses are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

Note a) The breaking strength referred to here is the mean breaking strength plus two standard deviations (as new from test data) of the component considered (generally chain) directly acting on or closest in the load path to the fairlead and stopper structures and is generally not to be taken lower than 110 per cent of the nominal minimum break strength of the component.

Note b) The design of structural arrangements around fairlead and mooring line connection area should consider the potential shock load from recoil in case of mooring line failure under tension.

1.1.8 When the minimum breaking strength of the main mooring line component directly connected to the structure, is governed by design aspects other than strength criteria, such as fatigue, LR will give special consideration to the use of the maximum breaking strength of the next component inline as long as the likelihood of the mooring line component directly connected to the structure being subject to a pull equal or greater than its maximum breaking strength can be disregarded on the basis of the conclusions of a risk assessment.)

1.1.9 Towing brackets and supporting structure are to be designed for a working load equal to the breaking strength of the towline in accordance with the requirements of *Pt 4, Ch 9 Anchoring and Towing Equipment*.

1.1.10 The supporting structure in way of lifeboat davits is to be designed for the dynamic factors defined in *Pt 4, Ch 4, 1.9 Lifeboat platforms* and the permissible stress levels are to comply with *Table 5.2.1 Factors of safety for the combined load cases* – load case (a) in *Pt 4, Ch 5, 2 Permissible stresses*.

1.1.11 The supporting structure to turret bearings on ship units is to comply with *Pt 10 SHIP UNITS*.

1.1.12 The scantlings of product swivels are to be determined in accordance with *Pt 3, Ch 13, 6 Mechanical items* and the supporting structure is to be integrated into the unit's hull structure and the local permissible stresses are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

1.1.13 The supporting structures to production and process plant are to comply with*Pt 3, Ch 8 Process Plant Facility*.

1.1.14 When a **DRILL** notation is to be assigned, the scantlings of the drilling derrick are to be determined in accordance with *Pt 3, Ch 7 Drilling Plant Facility*. The supporting sub-structure is a classification item and calculations are to be submitted in accordance with *Pt 3, Ch 7 Drilling Plant Facility*. The sub-structure is to be integrated into the unit's hull structure and the local permissible stresses are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

1.1.15 The application of the requirements for local scantlings to a column-stabilised unit is shown in *Pt 4, Ch 6, 1.1 General 1.1.15*.

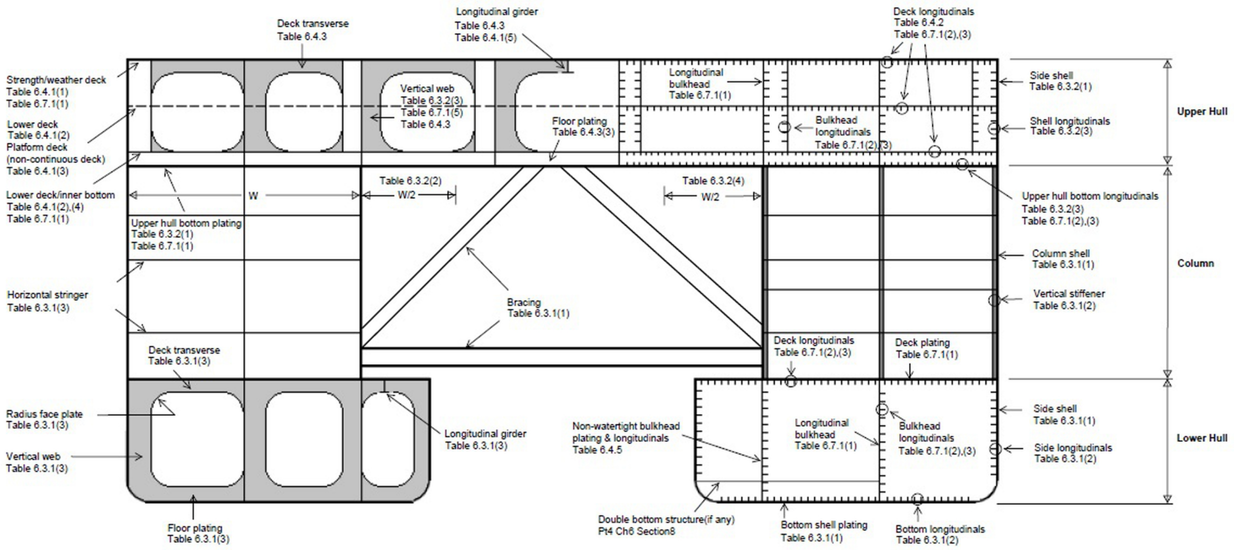


Figure 6.1.1 Application of the requirements for local scantlings to a column-stabilised unit

■ *Section 2* Design heads

2.1 General

2.1.1 This Section contains the local design heads and pressures to be used in the derivation of scantlings for decks, and bulkheads. Where scantlings in excess of Rule requirements are fitted the procedure to be adopted to determine the permissible head/pressure is also given.

2.2 Symbols

2.2.1 The symbols used in this Section are defined as follows:

L and *D* as defined in *Pt 4, Ch 1, 5 Definitions*

h_{i} = appropriate design head, in metres

p = design loading, in kN/m^2 (tonne-f/m^2)

p_{a} = applied loading, in kN/m^2 (tonne-f/m^3)

C = stowage rate, in m^3/tonne, *see Pt 4, Ch 6, 2.3 Stowage rate and design heads*

$= \dfrac{h_{\mathrm{i}}}{p}$

E = correction factor for height of platform

$$= \frac{0,0914 + 0,003L}{D - T} - 0,15, \text{ but not less than zero}$$

nor more than 0,147

T = T_o or T_T as defined in *Pt 4, Ch 1, 5 Definitions* as appropriate.

2.3 Stowage rate and design heads

2.3.1 The following standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general loading on decks.

(b) 0,975 m^3/tonne for tanks with liquid of density 1,025 tonne/m^3 or less on tank bulkheads and for watertight bulkheads. For liquid of density greater than 1,025 tonne/m^3, the corresponding stowage rates are to be adopted.

2.3.2 The design heads and permissible deck loading are shown in *Pt 4, Ch 6, 2.3 Stowage rate and design heads 2.3.2*. For helicopter landing areas, *see Pt 4, Ch 6, 5 Helicopter landing areas*.

Table 6.2.1 Design heads and permissible deck loadings (SI units)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p ,in kN/m^2	Equivalent design head h_i in metres	Permissible deck loading in kN-/m^2	Equivalent permissible head, in metres
1. Weather decks	—	—	—	h_1	—	—
(a) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	9,0 + 14,41E	1,28 + 2,04E	9,0	1,28
(b) Specified deck loading						
(i) Exposed deck	All structure	1,39	p_a + 14,41E but not less than (a) above	0,14 p_a + 2,04E	p_a	0,14 p_a
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	9,0	h_2 1,28	—	—
(ii) Storage areas	All structure	1,39	14,13	h_3 2,0	—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{9,82h}{C}$ (*see* Note 2)	h_4 h (*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	8,5	h_5 1,2	—	—
(b) Specified deck loading						
(i) All areas	All structure	1,39	p_a + 14,41E but not less than (a) above	h_2 h_3 h_5 0,14 p_a	—	—

(c) Superstructure decks (*see* Note 3				h_6			
(i) 1st tier	All structure	—	—	0,9	(*see* Note 4)	—	—
(ii) 2nd tier				0,6			
(iii) 3rd tier and above				0,45			
(d) Walkways and access areas	All structure	1,39	4,5	h_7		—	—
				0,64			
3. Watertight bulkheads	All structure	0,975	10,07 h_4	h_4	*see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	—	—
4. Deep tank bulkheads	All structure	*C* but ≤ 0,975	$\frac{9,82h_4}{C}$	h_4	*see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	—	—

NOTES

1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.
2. Where *h* equals half the distance to the top of the overflow above crown of tank.
3. For forecastle decks forward of 0,12*L* from F.P., *see* weather decks.
4. Where the deck is exposed to the weather add 2,04*E* to the design head.

Table 6.2.2 Design heads and permissible deck loadings (metric units)

Structural item and position	Component	Standard stowage rate *C*, in m^3/tonne	Design loading *p* ,in tonne — f/m^2	Equivalent design head h_i in metres	Permissible deck loading in tonne-f/m^2	Equivalent permissible head, in metres
1. Weather decks	—	—	—	h_1	—	—
(a) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	0,92 + 1,467*E*	1,28 + 2,04*E*	0,92	1,28
(b) Specified deck loading						
(i) Exposed deck	All structure	1,39	p_a + 1,467*E* but not less than (a) above	1,4 p_a + 2,04*E*	p_a	1,4 p_a
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	0,92	h_2	—	—
				1,28		

(ii) Storage areas	All structure	1,39	1,44		$\frac{h_3}{2,0}$		—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{h}{C}$	(*see* Note 2)	$\frac{h_4}{h}$	(*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	0,865		$\frac{h_5}{1,2}$		—	—
(b) Specified deck loading								
(i) All areas	All structure	1,39	p_a + 1,467E but not less than (a) above		$\frac{h_2\ h_3\ h_5}{0,14\ p_a}$		—	—
(c) Superstructure decks (*see* Note 3					h_6			
(i) 1st tier	All structure	—	—		0,9	(*see* Note 4)	—	—
(ii) 2nd tier					0,6			
(iii) 3rd tier and above					0,45			
(d) Walkways and access areas	All structure	1,39	0,46		$\frac{h_7}{0,64}$		—	—
3. Watertight bulkheads	All structure	0,975	$\frac{h_4}{0,975}$		h_4	*see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	—	—
4. Deep tank bulkheads	All structure	C but ≤ 0,975	$\frac{h_4}{C}$		h_4	*see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	—	—

NOTES

1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.

2. Where h equals half the distance to the top of the overflow above crown of tank.

3. For forecastle decks forward of 0,12L from F.P., *see* weather decks.

4. Where the deck is exposed to the weather add 2,04E to the design head.

■ *Section 3*
Watertight shell boundaries

3.1 General

3.1.1 The requirements of *Chapter 7* regarding watertight integrity are to be complied with.

3.1.2 The minimum requirements for watertight shell plating and framing of column-stabilised units, self-elevating units, tension-leg units, buoys and deep draught caissons are given in this Section.

3.1.3 The minimum requirements for watertight shell plating and framing of surface type units are to comply with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4, 4 Surface type units* for other surface type units.

3.1.4 The Rules are, in general, applicable to shell plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings are to be specially considered and the minimum shell thickness is to satisfy the buckling strength requirements given in *Pt 4, Ch 5 Primary Hull Strength*, but the minimum requirements of this Section are to be complied with.

3.1.5 The shell plating thickness is to satisfy the requirements for the overall strength of the unit in accordance with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength* for other unit types.

3.1.6 The scantlings of moonpool bulkheads will be specially considered with regard to the maximum forces imposed on the structure and the permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

3.1.7 The minimum scantlings of moonpool bulkheads on buoys and deep draught caissons are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons* and the load head h_0 in *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7* is to be measured to the top of the moonpool bulkhead.

3.1.8 The minimum scantlings of moonpools and drilling well bulkheads on column-stabilised and tension-leg units are to comply with *Pt 4, Ch 6, 3.2 Column-stabilised and tension-leg units 3.2.5*, but plating thickness is to be not less than 9,0 mm, *see also Pt 3, Ch 13, 2 Floating structures and subsea buoyant vessels*.

3.1.9 The scantlings of moonpools and drilling well bulkheads on surface type units and self-elevating units are to comply with *Pt 3, Ch 13, 2 Floating structures and subsea buoyant vessels*.

3.1.10 The scantlings of circumturret well bulkheads on ship units are to comply with *Pt 10 SHIP UNITS*.

3.1.11 Where column structures or superstructures extend over the side shell of the unit, the side shell/sheerstrake is to be suitably increased locally at the ends of the structure.

3.1.12 On units fitted with two chines each side the bilge plating should not be less than required for bottom plating. When units are fitted with hard chines the shell plating is not to be flanged, but where the chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is to be not less than three times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld, *see also Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7*.

3.1.13 The plating of swim ends is to have a thickness not less than that required for bottom shell plating.

3.1.14 Where a rounded sheerstrake is adopted, the radius should, in general, be not less than 15 times the plate thickness.

3.1.15 Sea inlets, or other openings, are to have well rounded corners and, so far as possible, are to be kept clear of the bilge radius. Openings on, or near to, the bilge radius are to be elliptical. The thickness of sea inlet box plating is to be the same as the adjacent shell, but not less than 12,5 mm. The ends of stiffeners should in general be bracketed and alternative proposals may be considered.

3.1.16 In general, secondary hull framing is to be continuous and the end connections of stiffeners to watertight bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of strength.

3.1.17 The end connections of secondary hull framing and primary members are to comply with:

- *Pt 10, Ch 3, 1 Scantling requirements* for ship units; and
- Chapter 8 for other unit types.

3.1.18 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with *Pt 4, Ch 5, 3 Buckling strength of plates and stiffeners*.

3.1.19 Web frames supporting secondary hull framing are, in general, to be spaced not more than 3,8 m apart when the length, L, is less than 100 m and (0,006L + 3,2) m apart where L is greater than 100 m. For units which are also required to operate aground, *see Pt 4, Ch 4, 2 Sea bed-stabilised units*.

3.2 Column-stabilised and tension-leg units

3.2.1 When the external watertight boundaries of columns, lower hulls and footings are designed with stiffened plating, the minimum scantlings for shell plating, hull framing and web frames, etc., are to comply with *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4*, *see also Pt 4, Ch 6, 3.2 Column-stabilised and tension-leg units 3.2.3*.

3.2.2 The scantlings determined from *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4* are the minimum requirements for hydrostatic pressure loads only and the overall strength is to comply with *Pt 4, Ch 4 Structural Unit Types*.

3.2.3 Where cross ties are fitted in columns or lower hulls, the scantlings are to comply with *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5* and *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.6* taking the head h_c as the pressure head h_o in accordance with *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4* as appropriate. Where cross ties are fitted inside tanks, the requirements of *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4* are also to be complied with.

3.2.4 When the scantlings of primary web frames or girders are determined by a frame analysis or where the boundaries of columns, lower hulls and footings are designed as shells either unstiffened or ring stiffened, the scantlings may be determined on the basis of an agreed analysis, *see Pt 4, Ch 1, 2 Direct calculations*. The minimum design loads are to be in accordance with *Pt 4, Ch 3 Structural Design* and the permissible stresses are to comply with *Pt 4, Ch 5 Primary Hull Strength*. The scantlings are not to be less than required by *Pt 4, Ch 6, 3.2 Column-stabilised and tension-leg units 3.2.1*.

3.2.5 The minimum scantlings of the external watertight boundaries of the upper hull structure are to comply with *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5*.

3.2.6 The shell plating and structure are to be reinforced in way of mooring fairleads, supply boat moorings, towing brackets and other attachments, *see also Pt 4, Ch 6, 1 General requirements*.

3.2.7 Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc., are to be protected or suitably strengthened.

3.2.8 Openings are not permitted in the shell boundaries of columns, lower hulls and footings except when they are closed with watertight covers fitted with closely spaced bolts, *see Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

3.3 Self-elevating units

3.3.1 The minimum scantlings of shell plating are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7* and the secondary hull framing and primary members are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7*, *see also Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4*.

3.3.2 The shell plating thickness is to be suitably increased in way of high shear forces in way of drilling cantilevers and other concentrated loads.

3.3.3 The scantlings and arrangements of the boundary bulkheads of leg wells will be specially considered with regard to the maximum forces imposed on the structure, and the permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength*. The minimum scantlings are to comply with *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4* as a tank bulkhead with the load head h_4 measured to the upper deck at side. In no case is the minimum plating thickness to be less than 9 mm.

3.3.4 When cross ties are fitted inside pre-load tanks, the tensile stress in the cross ties and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test head, but the scantlings are also to comply with the requirements of*Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5* and *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.6*.

Table 6.3.1 Watertight shell boundaries for lower hulls and columns of column-stabilised units and tension-leg units

Items and requirement	Boundaries of lower hull or columns
(1) Shell plating thickness *See also Pt 4, Ch 6, 3.1 General 3.1.5*	$t = 0{,}004 s f \sqrt{h_o k}$ mm but not less than 7,5 mm
(2) Hull framing: (a) Modulus (b) Inertia	 $Z = 6{,}4\, s\, k\, h_o\, l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2{,}3}{k}\, l_e\, Z$ cm^4

(3) Primary members: Web frames supporting framing:	
(a) Modulus	$Z = 6{,}4\, k\, h_o\, S\, l_e^{\,2}$ cm^3
(b) Inertia	$I = \frac{2{,}3}{k}\, l_e\, Z$ cm^4
Symbols	
$f = 1{,}1 - \frac{s}{2500S}$ but not to be taken greater than 1,0 h_0 = load head in metres measured vertically as follows: (a) For shell plating the distance from a point one-third of the height of the plate above its lower edge to a point 1,4 T_0 above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m. (b) For hull framing and primary members, the distance from the middle of the effective length to a point 1,4 T_0 above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m. k = steel factor as defined in *Pt 4, Ch 2, 1 Materials of construction* l_e = effective length of member, in metres, as defined in *Pt 4, Ch 3, 3.3 Determination of span point* s = spacing of frames, in mm S = spacing or mean spacing of primary members, in metres T_0 = maximum operating draught, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*	
NOTES 1. In no case are the scantlings in way of tanks to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for tank bulkheads using the load head h_4 . 2. In no case are the scantlings to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for watertight bulkheads using the load head h_4 . 3. Where frames are not continuous they are to be fitted with end brackets in accordance with *Pt 4, Ch 6, 7 Bulkheads* or equivalent arrangements provided.	

3.3.5 When cross ties are fitted to support shell web frames the scantlings of the web frames are to be determined from *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7* and *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4* and the area and least moment of inertia of the cross tie are to satisfy the following, *see also Pt 4, Ch 6, 3.3 Self-elevating units 3.3.6* and *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.7*:

$$A_c \geq \frac{0{,}82 b_c h_c S k}{1 - 0{,}42\left(\frac{l_c}{r\sqrt{k}}\right)}$$

where

b_c = one half the vertical distance in metres between the centres of the bottom or deck webs adjacent to the cross tie, *see Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5*

h_c = vertical distance from the centre of the cross tie to deck, in metres, *see Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5*

l_c = length of cross tie between the toes of the horizontal brackets on the web frames at the cross tie, in metres

S = spacing of web frames, in metres

l_e = span of web frames, *see Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5*

I_c = least inertia of cross tie cross-section, in cm^4

A_c = area of cross tie, in cm^2

r = least radius of gyration of cross tie cross-section, in cm

$= \sqrt{\frac{I_c}{A_c}}$

b_e as defined in *Pt 4, Ch 3, 3.3 Determination of span point*.

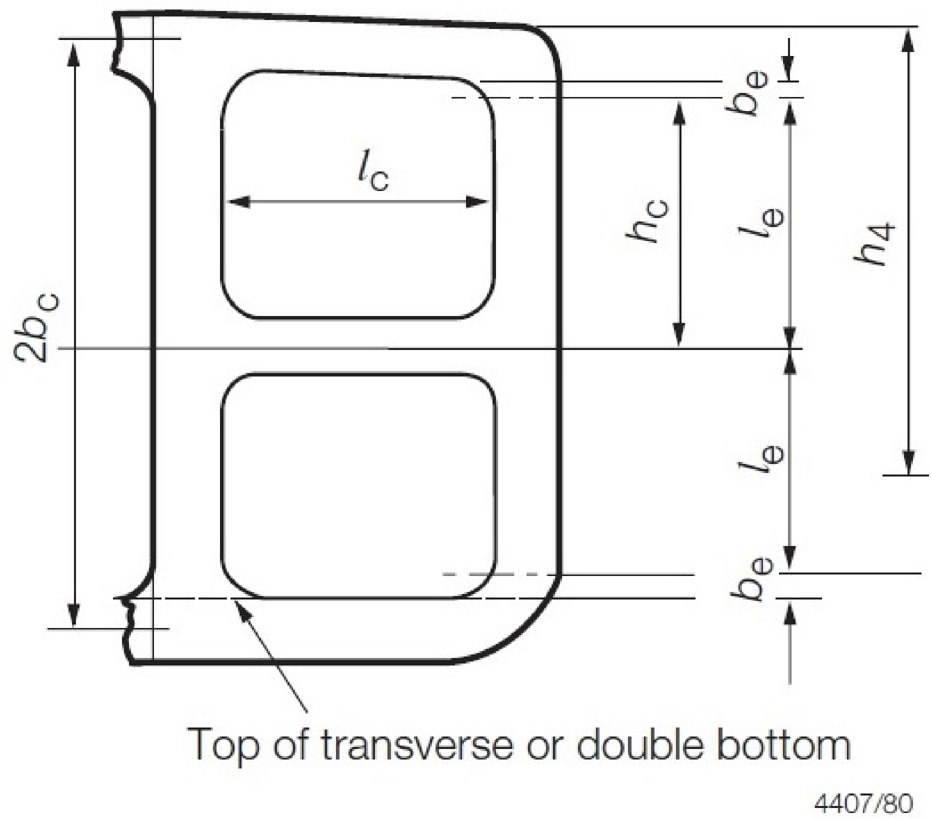


Figure 6.3.1 Cross tie construction

Table 6.3.2 Watertight shell boundaries of the upper hull of column-stabilised units and tension-leg units

Items and requirement	Boundaries of upper hull
(1) Shell plating thickness general *See also Pt 4, Ch 6, 3.1 General 3.1.5*	The greater of the following: (a) t = 0,004$sf\sqrt{h_4 k}$ mm (b) t = 0,012 $s_1\sqrt{k}$ but not less than 7,5 mm

(2) Bottom plating thickness between columns within $\frac{W}{2}$ outside of column shell but not less than two web frame spaces *See also Pt 4, Ch 6, 3.1 General 3.1.5*	The greater of the following: (a) t = 0,004s f $\sqrt{h_4 k}$ mm (b) t = 0,012 $s_1\sqrt{k}$ but not less than 7,5 mm
(3) Shell stiffeners and primary webs, general	To comply with *Table 6.7.1 Watertight and deep tank bulkhead scantlings* using the load head h_4
(4) Shell stiffeners adjacent to columns as defined in (2): (a) Modulus (b) Inertia	 $Z = 6{,}4\ s\ k\ h_4\ l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2,3}{k}\ l_e\ Z$ cm^4
Symbols	
Symbols as defined in *Table 6.7.1 Watertight and deep tank bulkhead scantlings*, except as follows: h_4 = load head, in metres, as defined in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for watertight bulkheads but not less than 6,0 m s_b = 470 + $\frac{L}{0,6}$ mm or 700, whichever is the smaller s_1 = s but is not to be taken less than s_b W = greatest width or diameter of stability column, in metres	
NOTES In no case are the scantlings in way of tanks to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for tank bulkheads using the load head h_4 .	

3.3.6 The scantlings of the webs and flanges of cross ties are to be checked for buckling by direct calculation.

3.3.7 Design of end connections of cross ties is to be such that the area of the welding, including vertical brackets, where fitted, is to be not less than the minimum cross sectional area of the cross tie derived from *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5*. To achieve this, full penetration welds may be required and thickness of brackets may require further consideration. Attention is to be given to the full continuity of area of the backing structure on the transverses. Particular attention is also to be paid to the welding at the toes of all end brackets on the cross tie.

3.4 Buoys and deep draught caissons

3.4.1 Where the external watertight hull boundaries are designed with stiffened plating, the minimum scantlings for shell plating, hull framing and web frames supporting framing, etc., are to comply with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7*.

3.4.2 The scantlings determined from *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7* are the minimum requirements for hydrostatic pressure loads only and the overall strength is to comply with *Pt 4, Ch 4 Structural Unit Types*.

3.4.3 Where the scantlings of primary web frames are determined by a frame analysis or where the boundaries are designed as shells, either unstiffened or ring stiffened, the scantlings are to be determined on the basis of an established analysis using the appropriate design pressure heads as defined in *Pt 4, Ch 3 Structural Design*. The permissible stresses are to comply with *Pt 4, Ch 5 Primary Hull Strength*, but the scantlings are not to be less than required by *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.1*.

3.4.4 The shell plating and hull framing are to be reinforced in way of mooring line attachments, mooring fairleads, supply boat moorings, towing brackets and other attachments, *see also Pt 4, Ch 6, 1 General requirements*.

3.4.5 Areas of the hull which may be damaged by chain cables or wire ropes are to be protected or suitably strengthened.

3.4.6 Where cross ties are fitted to support shell web frames, the scantlings are to comply with *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.5* and *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.6* taking the head h_c as the pressure head h_o in accordance with *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7*.

3.4.7 Where cross ties are fitted inside tanks, the requirements of *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4* are to be complied with.

Table 6.3.3 Shell plating self-elevating units

Location	Thickness, in mm, *see also Pt 4, Ch 6, 3.1 General 3.1.5*
(1) Bottom shell plating *See Notes* 1 and 3	$t = 0,0033 s_1 \sqrt{1,5 T_T k}$
(2) Bilge plating (framed) *See Note* 2	*t* as for (1)
(3) Side shell plating *See Notes* 1, 2 and 3	(a) Above $\frac{D}{2}$ from base: $t = 0,0033 s_1 \sqrt{1,4 T_T k}$ (b) At upper turn of bilge (*see* Note 1): $t = 0,0033 s_1 \sqrt{1,2 T_T k}$ (c) Between upper turn of bilge and $\frac{D}{2}$ from base: The greater of the following: (i) *t* from (b) (ii) *t* from interpolation between (a) and (b)
Symbols	
L, D, T_T , as defined in *Pt 4, Ch 1, 5 Definitions* *k* = steel factor as defined in *Pt 4, Ch 2, 1 Materials of construction* *s* = spacing of secondary stiffeners, in mm s_b = 470 + $\frac{L}{0,6}$ mm or 700 mm, whichever is the smaller s_1 = *s*, but is not to be taken less than s_b	
Note 1. When no bilge radius is fitted and the unit is fitted with hard chines, the bottom shell thickness required by (1) is, in general, to be extended up to $\frac{D}{4}$ from base, *see Pt 4, Ch 6, 3.1 General 3.1.10*. Note 2. The thickness of side shell need not exceed that determined from (1) for bottom shell when using the spacing of side shell stiffeners. Note 3. In no case are the scantlings of tanks to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for tank bulkheads using load head h_4 .	

Table 6.3.4 Shell framing self-elevating units

Items and location	Modulus
(1) Hull framing, *see Note* 1	

(a) Bottom frames	$Z = 6{,}4\ s\ k\ h_T\ l_e^2$ cm^3
(b) Side frames	$Z = 6{,}4\ s\ k\ h_T\ l_e^2$ cm^3
(2) Primary members, *see* Note 1	
(a) Bottom web frames supporting framing	$Z = 6{,}4k\ h_T\ S\ l_e^2 \times 10^{-3}$ cm^3
(b) Side web frames supporting framing	$Z = 6{,}4\ k\ h_T\ S\ l_e^2 \times 10^{-3}$ cm^3
Symbols	
D and T_T as defined in *Pt 4, Ch 1, 5 Definitions* h_T = load head, in metres, and is to be taken as the distance from the middle of the effective length to a point 1,6 T_T above the keel or to the upper deck at side whichever is the lesser but not less than 0,01*L* + 0,7 *k* = steel factor as defined in *Pt 4, Ch 2, 1 Materials of construction* l_e = effective length of member, in metres, as defined in *Pt 4, Ch 3, 3.3 Determination of span point* *s* = spacing of frames, in mm *S* = spacing or mean spacing of primary members, in metres	
NOTES 1. In no case are the scantlings in way of tanks to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for tank bulkheads using the load head h_4 . 2. In no case are the scantlings to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for watertight bulkheads using the load head h_4 . 3. Where frames are not continuous they are to be fitted with end brackets in accordance with *Pt 4, Ch 6, 7 Bulkheads* or equivalent arrangements provided.	

Table 6.3.5 Watertight shell boundaries of buoys and deep draught caissons

Items and requirement	Shell boundaries, *see* Note 5
(1) Shell plating thickness *See also Pt 4, Ch 6, 3.1 General 3.1.5*	$t = 0{,}004sf\sqrt{h_o\ k}$ mm but not less than 7,5 mm
(2) Hull framing:	
(a) Modulus	$Z = 6{,}4\ s\ k\ h_o\ l_e^2 \times 10^{-3}$ cm^3
(b) Inertia	$I = \frac{2{,}3}{k}\ l_e Z$ cm^4
(3) Primary members: Web frames supporting framing	
(a) Modulus	$Z = 6{,}4\ k\ h_o\ l_e^2 \times 10^{-3}$ cm^3
(b) Inertia	$I = \frac{2{,}5}{k}\ l_e Z$ cm^4
Symbols	
$f = 1{,}1 - \frac{s}{2500S}$ but not to be taken greater than 1,0	

h_o = load head in metres measured vertically as follows: (a) For shell plating the distance from a point one third of the height of the plate above its lower edge to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater with a minimum of 6,0 m, *see* Note 3 (b) For hull framing and primary members, the distance from the middle of the effective length to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater, with a minimum of 6,0 m, *see* Note 3 *k* = steel factor as defined in *Pt 4, Ch 2, 1 Materials of construction* l_e = effective length of member in metres as defined in *Pt 4, Ch 3, 3.3 Determination of span point* *s* = spacing of frame in mm *S* = spacing or mean spacing of primary members, in metres
NOTES 1. In no case are the scantlings in way of tanks to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for tank bulkheads using the load head h_4 . 2. In no case are the scantlings to be less than the requirements given in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* for watertight bulkheads using the load head h_4 . 3a. For shell plating of units defined in *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures* which are designed to follow the wave profile, h_o need not exceed the distance measured from a point one third of the height of the plate above its lower edge to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater. (But note that *t* shall not be less than 9,0 mm.) 3b. For hull framing of units defined in *Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures*which are designed to follow the wave profile, h_o need not exceed the distance measured from the middle of the effective length to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater, but h_o shall not be less than the h_o calculated from the shell plating thickness formulation (*Table 6.3.5 Watertight shell boundaries of buoys and deep draught caissons* (1)) that corresponds to the minimum thickness requirement of 9,0 mm. 4. Where frames are not continuous they are to be fitted with end brackets in accordance with *Pt 4, Ch 6, 7 Bulkheads* or equivalent arrangements provided. 5. The scantlings of shell boundaries derived from this Table are to be suitably increased in way of tanks which cannot be inspected at normal periodic surveys, *see Pt 4, Ch 4, 7.10 Corrosion protection*.

■ *Section 4* **Decks**

4.1 General

4.1.1 The design deck loadings for all unit types are not to be less than those defined in *Pt 4, Ch 6, 1 General requirements* and *Pt 4, Ch 6, 2 Design heads*.

4.1.2 The scantlings of deck structures are to comply with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4, 4 Surface type units* for other surface type units.

The requirements of *Pt 4, Ch 6, 4.1 General 4.1.5* and *Pt 4, Ch 6, 4.1 General 4.1.6* are also to be complied with as applicable.

4.1.3 The minimum scantlings of deck structures on column-stabilised units, self-elevating units, tension-leg units, buoys and deep draught caissons are to comply with this Section.

4.1.4 The scantlings of deck structures are also to satisfy the overall strength requirements in *Pt 4, Ch 4 Structural Unit Types* and be sufficient to withstand the actual local loadings plus any additional loadings superimposed due to overall frame action. The permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

4.1.5 Where decks form watertight boundaries in damage stability conditions, the minimum scantlings are not to be less than required for watertight bulkheads given in *Pt 4, Ch 6, 7 Bulkheads*.

4.1.6 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures to drilling derricks and flare structures, etc., are considered to be classification items regardless of whether or not the process/drilling plant facility is classed and the loadings are to be determined in accordance with *Pt 3, Ch 8, 2 Structure*. Permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength*.

4.2 Deck plating

4.2.1 The requirements are in general applicable to strength/weather deck plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings will be specially considered, but the minimum requirements of *Pt 4, Ch 6, 4.3 Deck stiffening 4.3.3* are to be complied with.

4.2.2 The minimum thickness of deck plating is to comply with the requirements of *Pt 4, Ch 6, 4.3 Deck stiffening 4.3.3*, except for decks in way of erections above the upper deck. For erection decks, *see Pt 4, Ch 6, 6 Decks loaded by wheeled vehicles*.

4.2.3 The thickness of strength/weather deck plating is also to be that necessary to satisfy the overall strength requirements of:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength* for other unit types.

4.2.4 The deck plating thickness and supporting structure in way of towing brackets, winches, masts, crane pedestals, davits and machinery items, etc., is to be suitably reinforced, *see also Pt 4, Ch 6, 1 General requirements*.

4.2.5 Where plated decks are sheathed with wood or approved compositions, consideration will be given to allowing a reduction in the minimum plating thickness given in *Pt 4, Ch 6, 4.3 Deck stiffening 4.3.3*.

4.3 Deck stiffening

4.3.1 The scantlings of deck stiffeners are to comply with the requirements of *Table 6.4.2 Deck Stiffeners*. Stiffeners fitted in way of concentrated loads and heavy machinery items, etc., will be specially considered.

4.3.2 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with *Pt 4, Ch 5, 3 Buckling strength of plates and stiffeners*.

4.3.3 End connection of stiffeners to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of primary strength. In general deck stiffeners are to be continuous through primary support structure, including bulkheads but alternative arrangements will be considered. The end connections of stiffeners are in general to be in accordance with the requirements of *Pt 4, Ch 8 Welding and Structural Details*.

Table 6.4.1 Deck plating

Symbols	Location	Thickness, in mm, *see also Pt 4, Ch 6, 4.2 Deck plating 4.2.2*
b = breadth of increased plating, in mm *f* = 1,1 – $\frac{s}{2500S}$ but not to be taken greater than 1,0 *k* = steel factor as defined in 2.1.2	(1) Strength/weather deck *See* Notes 1 and 2	*t* = 0,00083 $s_1 \sqrt{Lk}$ but not less than (2)

s = spacing of deck stiffeners, in mm s_1 = s but is to be taken not less than the smaller of: $470 + \frac{L}{0,6}$ mm or 700 mm A_f = cross sectional area of girder face plate, in cm^2	(2) Lower decks	$t = 0,012\ s_1 \sqrt{k}$ but not less than 7,0 mm
	(3) Platform decks	$t = 0,01\ s_1 \sqrt{k}$ but not less than 6,5 mm
L = length of unit, in metres, as defined in *Pt 4, Ch 1, 5.1 General* S = spacing of primary members, in metres	(4) In way of the crown or bottom of tanks	$t = 0,004sf \sqrt{\frac{\rho\, k\, h_4}{1,025}}$ or as (1), (2) or (3) whichever is the greater but not less than 7,5 mm
ρ, h_4 as defined in *Table 6.7.1 Watertight and deep tank bulkhead scantlings*	(5) Plating forming the upper flange of underdeck girders	$t = \sqrt{\frac{A_f}{1,8k}}$ but not less than required by (1), (2), (3) or (4) as appropriate to the location of the plating Minimum breadth, b = 760 mm
NOTES 1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of *Pt 4, Ch 5 Primary Hull Strength*. 2. On column-stabilised units when the primary deck structure consists of box girders or equivalent structure and the deck plating is considered as secondary structure only the thickness of the plating will be specially considered but in no case is the thickness to be less than 6,5 mm. 3. Where the local deck loading exceeds 43,2 kN/m^2(4,4 tonne-f/m^2) the thickness of plating will be specially considered.		

4.4 Deck supporting structure

4.4.1 The minimum scantlings of girders and transverses supporting deck stiffeners are to comply with the requirements of *Table 6.4.3 Deck girders, transversers and deep beams*.

4.4.2 Transverses supporting deck longitudinals are, in general, to be spaced not more than 3,8 m apart when the length, L, is 100 m or less, and (0,006L + 3,2) m apart where L is greater than 100 m.

Table 6.4.2 Deck Stiffeners

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
d_w = depth of stiffener, in mm, *see* Note 2 h_1 = weather head, in metres	(1) Weather decks	$Z = 4,5s\ k\ h_1\ l_e^{\ 2} \times 10^{-3}$	—
h_2 = work area head, in metres h_3 = storage head, in metres	(2) Work areas	$Z = 4,5s\ k\ h_2\ l_e^{\ 2} \times 10^{-3}$	—
h_4 = tank head, in metres, as defined in *Table 6.7.1 Watertight and deep tank bulkhead scantlings* h_5 = accommodation head, in metres	(3) Storage areas	$Z = 4,5s\ k\ h_3\ l_e^{\ 2} \times 10^{-3}$	—
k = steel factor defined in *Pt 4, Ch 2, 1.2 Steel* l_e = span point, in metres as defined in *Pt 4, Ch 6, 3.3 Self-elevating units* but not less than 1,5 m	(4) Accommodation decks and crew spaces	$Z = 4,5s\ k\ h_5\ l_e^{\ 2} \times 10^{-3}$	—

s = spacing of stiffeners, in mm γ = 1,4 for rolled or built sections = 1,6 for flat bars ρ as defined in *Table 6.7.1 Watertight and deep tank bulkhead scantlings*	(5) In way of the crown or bottom of tanks	As (1), (2), (3) or (4) as applicable, or $\frac{0,0113\,\rho\;s\,k\,h_4\,l_e^2}{\gamma}$ whichever is the greater	$I = \frac{2,3}{k}\,l_e Z$
NOTES 1. The load heads h_1 , h_2 , h_3 and h_5 are to be determined from the maximum design uniform loadings and are not to be less than the minimum design load heads given in *Table 6.2.1 Design heads and permissible deck loadings (SI units)*. 2. The web depth, d_w , of stiffeners is to be not less than 60 mm.			

Table 6.4.3 Deck girders, transversers and deep beams

Location and arrangements	Modulus, in cm^3	Inertia, in cm^4
(1) Girders and transverses in way of dry spaces: (a) Supporting point loads (b) Supporting a uniformly distributed load	Z to be determined from calculations using stress $\frac{123,5}{k}\mathrm{N/mm^2}\left(\frac{12,6}{\mathrm{k}}\ \mathrm{kgf/mm^2}\right)$ and assuming fixed ends Z = 6,4 k S $H_g l_e^2$	$I = \frac{1,85}{k}\,l_e Z$
(2) Deep beams supporting deck girders in way of dry spaces: (a) Supporting point loads (b) Supporting a uniformly distributed load	Z to be determined from calculations using stress $\frac{123,5}{k}\mathrm{N/mm^2}\left(\frac{12,6}{\mathrm{k}}\ \mathrm{kgf/mm^2}\right)$ and assuming fixed ends Z = 6,4 k S $H_g l_e^2$	$I = \frac{2,3}{k}\,l_e Z$
(3) Girders and transverses in way of the crown or bottom of tanks	Z = 9,6ρk $h\,S\;l_e^2$	$I = \frac{2,5}{k}\,l_e Z$
Symbols		
h_4 = tank head, in metres, as defined in*Table 6.7.1 Watertight and deep tank bulkhead scantlings* k = steel factor as defined in *Pt 4, Ch 2, 1.2 Steel* l_e = span point, in metres, defined in *Pt 4, Ch 6, 3.3 Self-elevating units* H_g = weather head h_1 or work area head h_2 or storage head h_3 or accommodation head h_5 , in metres, as defined in *Table 6.2.1 Design heads and permissible deck loadings (SI units)* whichever is applicable S = spacing of primary members, in metres ρ as defined in*Table 6.7.1 Watertight and deep tank bulkhead scantlings*		

4.4.3 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with *Pt 4, Ch 8 Welding and Structural Details*.

4.4.4 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased. Also, where concentrations of loading on one side of the girder may occur, the girder is to be adequately stiffened against torsion.

4.4.5 Pillars are to comply with the requirements of *Pt 4, Ch 6, 4.4 Deck supporting structure 4.4.6*.

4.4.6 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

Table 6.4.4 Pillars

Symbols	Parameter	Requirement
b = breadth of side of a hollow rectangular pillar or breadth of flange or web of a built or rolled section, in mm d_{p} = mean diameter of tubular pillars, in mm	(1) Cross-sectional area of all types of pillar	$A_{\text{p}} = \dfrac{k\,P}{12,36 - 51,5\dfrac{l_e}{r\sqrt{k}}}$ cm^2 $\left(A_{\text{p}} = \dfrac{k\,P}{1,26 - 5,25\dfrac{l_e}{r\sqrt{k}}} \text{ cm}^2 \right)$ *See* Note
k = local scantling higher tensile steel factor, *see Pt 4, Ch 2, 1.2 Steel 1.2.1*, but not less than 0,72 *l* = overall length of pillar, in metres l_{e} = effective length of pillar, in metres, and is taken as 0,80*l*	(2) Minimum wall thickness of tubular pillars	The greatest of the following: (a) $t = \dfrac{P}{0,392d_{\text{p}} - 4,9l_{\text{e}}}$ mm $\left(t = \dfrac{P}{0,04d_{\text{p}} - 0,5l_{\text{e}}} \text{ mm} \right)$ (b) $t = \dfrac{d_{\text{p}}}{40}$ mm (c) *t* = 5,5 mm where *L* < 90 m, or = 7,5 mm where *L* ≥ 90 m
r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I}{A_{\text{p}}}}$ mm A_{p} = cross-sectional area of pillar, in cm^2	(3) Minimum wall thickness of hollow rectangular pillars or web plate thickness of I or channel sections	The lesser of the following: (a) $t = \dfrac{b\,r}{600l_{\text{e}}}$ mm (b) $t = \dfrac{b}{55}$ mm but to be not less than *t* = 5,5 mm where *L* < 90 m, or = 7,5 mm where *L* ≥ 90 m
H_{g} as defined in *Pt 4, Ch 6, 4.4 Deck supporting structure 4.4.2* *I* = least moment of inertia of cross-section, in cm^4 *P* = load, in kN (tonne-f), supported by the pillar and is to be taken as: $P = P_{\text{o}} + P_{\text{a}}$ but not less than 19,62 kN (2 tonne-f)	(4) Minimum thickness of flanges of angle or channel sections	The lesser of the following: (a) $t_{\text{f}} = \dfrac{b\,r}{200l_{\text{e}}}$ mm (b) $t_{\text{f}} = \dfrac{b}{18}$ mm

P_a = load, in kN (tonne-f), from pillar or pillars above (zero if no pillars over) P_o = load, in kN (tonne-f), supported by pillar based on H_g	(5) Minimum thickness of flanges of built or rolled I sections	The lesser of the following: (a) $t_f = \frac{b\,r}{400 l_e}$ mm (b) $t_f = \frac{b}{36}$ mm
NOTE As a first approximation, A_p may be taken as $\frac{\sqrt{k}\,P}{9,32}\left(\frac{\sqrt{k}P}{0,95}\right)$ and the radius of gyration estimated for a suitable section having this area. If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximation is to be made.		

4.4.7 Tubular and hollow square pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

4.4.8 Where pillars are not fitted directly above the intersection of bulkheads, equivalent arrangements are to be provided.

4.4.9 In double bottoms where pillars are not directly above the intersection of the plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in floors and girders below the heels of pillars.

4.4.10 Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test heads. In general, such pillars should be of built sections, and end brackets may be required.

4.4.11 Pillars or equivalent structures are to be fitted below deckhouses, machinery items, winches, etc., and elsewhere where considered necessary.

4.4.12 The thickness of primary longitudinal and transverse bulkheads supporting decks is to satisfy the requirements for the overall strength of the unit in accordance with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength* for other unit types.

When the bulkheads are to be watertight the scantlings are also to comply with the requirements of *Pt 4, Ch 6, 7 Bulkheads*.

4.4.13 The lateral and torsional stability of primary bulkhead stiffeners together with web and flange buckling criteria are to be verified in accordance with *Pt 4, Ch 5, 3 Buckling strength of plates and stiffeners*.

4.4.14 When openings are cut in the primary longitudinal and transverse bulkheads the openings are to have well rounded corners and full compensation is to be provided. All openings are to be adequately framed.

4.4.15 The minimum scantlings of non-watertight pillar bulkheads are to comply with the requirements of *Pt 4, Ch 6, 4.5 Deck openings 4.5.7*.

4.5 Deck openings

4.5.1 The corners of all deck openings are to be elliptical, parabolic or well rounded and the free edges are to be smooth. Large openings are to comply with *Pt 4, Ch 6, 4.5 Deck openings 4.5.4* and *Pt 4, Ch 6, 4.5 Deck openings 4.5.5*.

4.5.2 All openings are to be adequately framed. Attention is to be paid to structural continuity, and abrupt changes of shape, section or plate thickness are to be avoided.

4.5.3 Arrangements in way of corners and openings are to be such as to minimise the creation of stress concentrations. Openings in highly stressed areas of decks, having a stress concentration factor in excess of 2,4, will require edge reinforcements in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening

4.5.4 When large openings are cut in highly stressed areas of decks, the corners of the openings are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening. The minimum radius for large openings is to be 150 mm, provided the inner edge of the plating is stiffened by means of a coaming or spigot. Where the inner edge is unstiffened, the minimum radius is to be 300 mm.

4.5.5 Where the corners of large openings are rounded, the deck plating thickness is to be increased at the corners of the openings.

4.5.6 Compensation will be required for deck openings cut in highly stressed areas.

4.5.7 All openings which are required to be made watertight or weathertight are to have closing appliances in accordance with the requirements of *Chapter 7*.

Table 6.4.5 Non-watertight pillar bulkheads

<table>
<tr><th>Symbols</th><th>Parameter</th><th colspan="2">Requiremet</th></tr>
<tr><td rowspan="5">d_w , t_p , b, c as defined in Pt 4, Ch 3, 3.2 Geometric properties of section

r = radius of gyration, in mm, of stiffener and attached plating

= $10\sqrt{\frac{I}{A}}$ mm for rolled, built

or swedged stiffeners

= $d_w\sqrt{\frac{3\,b+c}{12\,(b+c)}}$ mm for symmetrical corrugation

s = spacing of stiffeners, in mm

I = moment of inertia, in cm^4, of stiffener and attached plating

A = cross-sectional area, in cm^2, of stiffener and attached plating

$A_1 = \frac{P}{12,36 - 51,5\frac{l_e}{r}}\ \text{cm}^2$

$\left(A_1 = \frac{P}{1,26 - 5,25\frac{l_e}{r}}\ \text{cm}^2\right)$

As a first approximation A_1 may be taken as

$\frac{P}{9,32}\left(\frac{P}{0,95}\right)$

$A_2 = \frac{P}{4,9 - 14,7\frac{l_e}{r}}\ \text{cm}^2$

$\left(A_2 = \frac{P}{0,5 - 1,5\frac{l_e}{r}}\ \text{cm}^2\right)$

As a first approximation A_2 may be taken as

$\frac{P}{3,92}\left(\frac{P}{0,4}\right)$

P, l_e as defined in Pt 4, Ch 6, 4.4 Deck supporting structure 4.4.6

$\lambda = \frac{b}{c}$</td>
<td>(1) Minimum thickness of bulkhead plating</td><td colspan="2">5,5 mm</td></tr>
<tr><td>(2) Maximum stiffener spacing</td><td colspan="2">1500 mm</td></tr>
<tr><td>(3) Minimum depth of stiffeners or corrugations</td><td colspan="2">75 mm</td></tr>
<tr><td>(4) Cross-sectional area (including plating) for rolled, built or swedged stiffeners supporting beams, longitudinals, girders or transverses</td><td>(a) Where $\frac{s}{t} \le 80$

(b) When $\frac{s}{t} \ge 120$

(c) Where $80 < \frac{s}{t} < 120$</td><td>$A = A_1$

$A = A_1$

A is obtained by interpolation between A_1 and A_2</td></tr>
<tr><td>(5) Cross-sectional area (including plating) for symmetrical corrugation</td><td>(a) Where $\frac{b}{t_p} \le \frac{750\,\lambda\,l_e}{(\lambda + 0,25)r}$

(b) Where $\frac{b}{t_p} > \frac{750\,\lambda\,l_e}{(\lambda + 0,25)r}$</td><td>$A = A_1$

$A = A_2$</td></tr>
</table>

■ *Section 5*
Helicopter landing areas

5.1 General

5.1.1 This Section gives the requirements for decks intended for helicopter operations on all unit types.

5.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the unit. These include the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* and *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, CAP 437 7th edition, NMA/NMD 2013 and ISO 19901-3:2011, as applicable. Guidance on the provision and operation of helicopter landing or winching facilities may be drawn from international Standards such as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations* and the *International Aeronautical Search and Rescue Manual (IAMSAR).*

5.1.3 Where helicopter decks are positioned so that they may be subjected to wave impacts, the scantlings are to be considered in a realistic manner and increased to the satisfaction of LR. Calculations are to be submitted for consideration.

5.1.4 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.2 Plans and data

5.2.1 Plans and data are to be submitted giving the arrangements, scantlings and details of the helicopter deck. The type, size, weight and footprint of helicopters to be used are also to be indicated.

5.2.2 Relevant details of the largest helicopters, for which the deck is designed, are to be stated in the Operations Manual.

5.3 Arrangements

5.3.1 The landing area is to comply with applicable Regulations, International Standards or to the satisfaction of the National Authority, with respect to size, landing and take-off sectors of the helicopter, freedom from height obstructions, deck markings, safety nets and lighting, etc.

5.3.2 The landing area is to have an overall coating of non-slip material or other arrangements are to be provided to minimise the risk of personnel or helicopters sliding off the landing area.

5.3.3 A drainage system is to be provided in association with a perimeter guttering system or slightly raised kerb to prevent spilled fuel falling on to other parts of the unit. The drains are to be led to a safe area.

5.3.4 A sufficient number of tie-down points are to be provided to secure the helicopter.

5.3.5 Engine and boiler uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take-off or landing operations.

5.4 Landing area plating

5.4.1 Helideck support structures should be designed to carry all the loads imposed on the helideck through to the primary structure of the unit. Helideck loads derive from the parameters of the helicopter for which the helideck is intended (landing impact forces and wheel spacing), the deck weight, plus environmental loads (wind, snow and ice), and inertial loads due to unit movement, as applicable. Additionally, the effects of live loads and loads arising from parked helicopters (tied down) should be evaluated.

5.4.2 The designer of the support structure should ensure that all appropriate load cases have been applied to the helideck, and that the resulting maximum load cases are used in the design of the support structure. Similarly, it is important that the load cases are accurately transposed to the design conditions for the primary structure to which the support structure will be connected.

5.5 Load combination

5.5.1 The helicopter landing area is to be considered with respect to design loads resulting from the following conditions:

(a) Emergency landing
(b) Normal operation and
(c) Helicopter at rest

5.5.2 **Emergency landing** The following loads are to be considered in helicopter emergency landing condition.

(a) Helicopter landing dynamic loads: For an emergency landing, an impact load of 2,5 x the maximum take-off weight (MTOW) of the helicopter should be applied in any position on the landing area together with the combined effects of *Pt 4, Ch 6, 5.5 Load combination 5.5.2* to *Pt 4, Ch 6, 5.5 Load combination 5.5.2* inclusive.

(b) Structural response factor for supporting structure: The helicopter landing dynamic loads shall be increased by a structural response factor to account for the sympathetic response of the helideck structure. The factor to be applied for the design of the helideck framing depends on the natural frequency of the deck structure. Unless values based upon particular undercarriage behaviour and deck frequency are available, a minimum structural response factor of 1,3 shall be used.

(c) Area loads: A general area-distributed load of 0,5 kN/m^2 shall be applied to allow for minor equipment left on the helideck and for any snow and ice loads.

(d) Horizontal loads as a proportion of MTOW: Concentrated horizontal imposed loads equivalent in total to half the maximum take-off weight of the helicopter shall be applied at the locations of the main undercarriages and distributed in proportion to the vertical loads at each point. These shall be applied at deck level in the horizontal direction that will produce the most severe load case for the structural component being considered.

(e) Self weight of structure and fixed appurtenances: The self weight of the helideck structure and fixed appurtenances supported by each structural component concerned shall be evaluated.

(f) Wind loads: Wind loads on the helideck structure shall be applied in the direction which, together with the horizontal imposed loads, produces the most severe load case for the structural component considered. The wind speed to be considered shall be that restricting normal (non-emergency) helicopter operations at the platform. Any vertical action on the helideck structure due to the passage of wind over and under the helideck shall be considered.

(g) Inertial loads: The effect of accelerations and dynamic amplification arising from the predicted motions of the fixed or floating platform in a storm condition with a 10 year return period shall be considered.

5.5.3 **Normal operations** The following loads are to be considered in helicopter normal operation condition

(a) Helicopter landing dynamic loads: For a normal operation, an impact load of 1,5 x the maximum take-off weight (MTOW) of the helicopter should be applied in any position on the landing area together with the combined effects of *Pt 4, Ch 6, 5.5 Load combination 5.5.3* to *Pt 4, Ch 6, 5.5 Load combination 5.5.3* inclusive.

(b) Structural response factor for supporting structure: The helicopter landing dynamic loads shall be increased by a structural response factor to account for the sympathetic response of the helideck structure. The factor to be applied for the design of the helideck framing depends on the natural frequency of the deck structure. Unless values based upon particular undercarriage behaviour and deck frequency are available, a minimum structural response factor of 1,3 shall be used.

(c) Area loads: To allow for personnel, freight, refuelling equipment and other traffic, snow and ice, rotor downwash, etc., a general area load of 0,5 kN/m^2 shall be included.

(d) Horizontal loads as proportion of MTOW: Concentrated horizontal imposed loads equivalent in total to half the maximum take-off weight of the helicopter shall be applied at the locations of the main undercarriages and distributed in proportion to the vertical loads at each point. These shall be applied at deck level in the horizontal direction that will produce the most severe load case for the structural component being considered.

(e) Self weight of structure and fixed appurtenances.

(f) Wind loads: The 100 year return period wind loads on the helideck structure shall be applied in the direction which produces the most severe load case for the structural component considered.

(g) Inertial loads: The effect of accelerations and dynamic amplification arising from the predicted motions of the fixed or floating platform in a storm condition with a 10 year return period shall be considered.

5.5.4 **Helicopter at rest** The following loads are to be considered in helicopter at rest condition

(a) Helicopter static loads (local patch loads on landing gear): All parts of the helideck accessible to helicopters shall be designed to support a load equal to the MTOW of the helicopter at any location. This shall be distributed at the undercarriage locations in proportion to the position of the centre of gravity of the helicopter, taking account of possible different positions and orientations of the helicopter.

(b) Area loads: To allow for personnel, freight, refuelling equipment and other traffic, snow and ice, rotor downwash, etc., a general area load of 2,0 kN/m^2 shall be included.

(c) Horizontal loads from tie down helicopter, including wind loads from a secured helicopter: Each tie-down shall be designed to resist the calculated proportion of the total wind action on the helicopter imposed by a storm wind with a minimum one year return period.

(d) Self weight of structure and fixed appurtenances.

(e) Wind loads: The 100 year return period wind loads on the helideck structure shall be applied in the direction which produces the most severe load case for the structural component considered.

(f) Inertial loads: The effect of accelerations and dynamic amplification arising from the predicted motions of the fixed or floating platform in a storm condition with a 10 year return period shall be considered.

5.5.5 Deck plate and stiffeners shall be designed to limit the permanent deflection (deformation) under helicopter emergency landing conditions to no more than 2,5 % of the clear width of the plates between supports.

5.6 Landing area plating

5.6.1 The deck gross plate thickness, t, within the landing area is to be not less than:

$t = t_1 + 1{,}5$ mm

where

$t_1 = \dfrac{\alpha s}{1000\sqrt{k}}$ mm

α = thickness coefficient obtained from *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*

β = tyre print coefficient used in *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*

$= \log_{10}\left(\dfrac{P_1 k^2}{s^2} \times 10^7\right)$

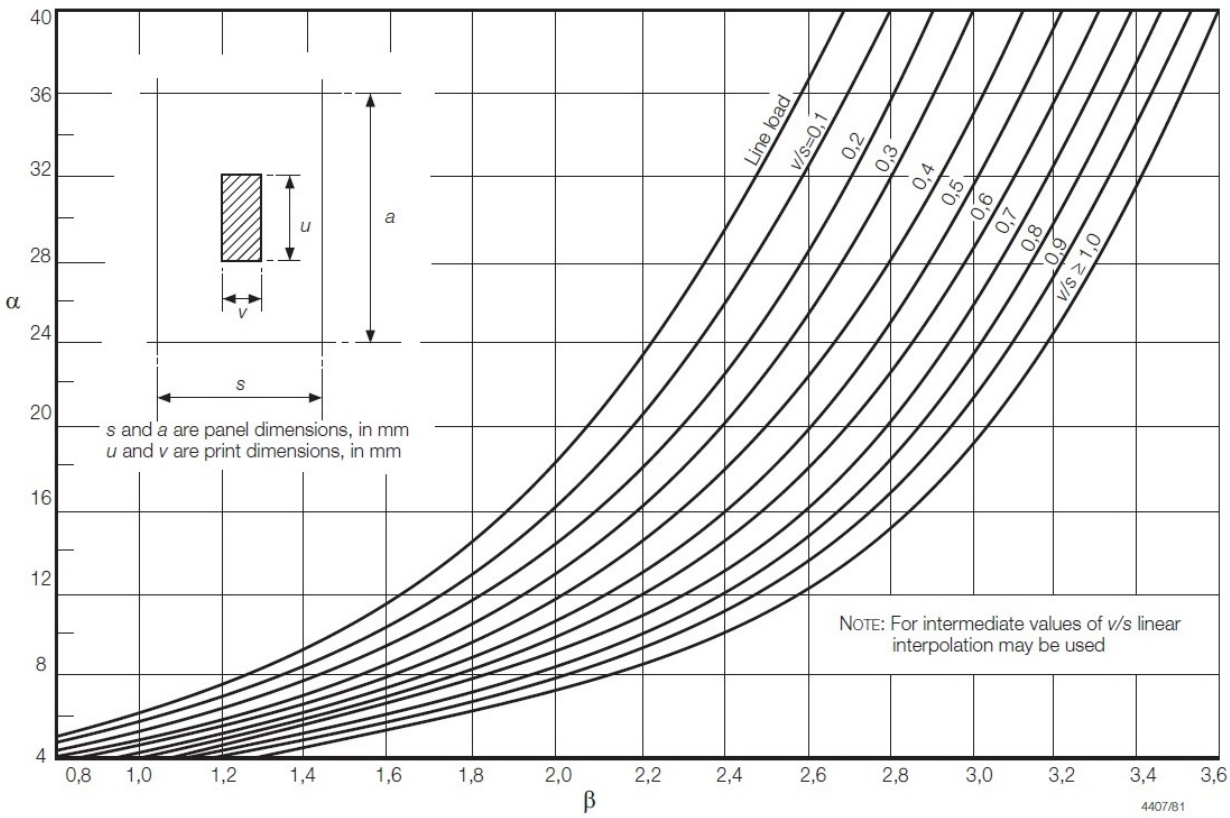


Figure 6.5.1 Tyre print chart

The plating is to be designed for the emergency landing case taking:

$P_1 = 2{,}5\,\varphi_1\,\varphi_2\,\varphi_3\,f_\gamma\,P_w$ tonnes

where

φ_1 φ_2 φ_3 are to be determined from *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2*

f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes;

For helicopters with a single main rotor, P_w , is to be taken as P_h divided equally between the two main undercarriage wheels.
For helicopters with tandem main rotors, P_w , is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.
For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as 1/6 P_h for each of the two forward contact points and 1/3 P_h for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*.

γ = 0,6 generally. Factor to be specially considered where the helicopter deck contributed to the overall strength of the unit

Other symbols used in this Section are defined in Section 6 and in the appropriate sub-Section.

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown, it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plans.
For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*.

5.6.2 The plate thickness for aluminium decks is to be not less than:

t = 1,4 t_1 + 1,5 mm

where

t_1 is the mild steel thickness as determined from *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*.

Where the deck is fabricated using extruded sections with closely spaced stiffeners the plate thickness may be determined by direct calculations but the minimum deck thickness is to include 1,5 mm wear allowance. If the deck is protected by closely spaced grip/wear treads the wear allowance may be omitted.

5.7 Deck stiffening and supporting structure

5.7.1 The helicopter deck stiffening and the supporting structure for helicopter decks are to be designed for the load cases given in *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2* in association with the permissible stresses given in *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2*. The helicopter is to be positioned so as to produce the most severe loading condition for each structural member under consideration.

5.7.2 In addition to the requirements of *Pt 4, Ch 6, 5.5 Load combination 5.5.1*, the structure supporting helicopter decks is to be designed to withstand the loads imposed on the structure due to the motions of the unit. For self-elevating units, the motions are not to be less than those defined for transit conditions in *Pt 4, Ch 4, 3.10 Legs in field transit conditions* and *Pt 4, Ch 4, 3.11 Legs in ocean transit conditions*. The stress levels are to comply with load case 3 in *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2*, *see also Pt 4, Ch 6, 5.1 General 5.1.3*.

Table 6.5.1 Design load cases for deck stiffening and supporting structure

Load cases	Load				
	Landing area		Supporting structure *See* Note 1		
	Area load, in kN/m^2	Helicopter patch load *See* Note 2	Self-weight	Wind load, return period in years	Inertia load, return period in years
(1) Helicopter emergency landing	0,5	2,5 $P_w f$	W_h	*See Pt 4, Ch 6, 5.5 Load combination 5.5.2*	10
(2) Normal operation	0,5	1,5 P_w	W_h	100	10
(3) Helicopter at rest	2,0	P_w	W_h	100	10

Symbols

P_h , P_w and *f* as defined in *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1*

W_h = structural self-weight of helicopter platform

NOTES

1. For the design of the supporting structure for helicopter platforms applicable horizontal load, self-weight, wind load and inertia load are to be added to the landing area loads.

2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

3. For the emergency landing and normal operation, helicopter patch load shall be increased by a suitable structural response factor depending upon the natural frequency of the helideck structure. It is recommended that a structural response factor of 1,3 should be used unless further information allows a lower factor to be calculated.

Table 6.5.2 Permissible stresses for deck stiffening and supporting structure

Load case *See Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2*	Permissible stresses, in N/mm^2			
	Deck secondary structure (beams, longitudinals, deck plating *See* Notes 1 and 2)	Primary structure (transverses, girders, pillars, trusses)		All structure
	Bending		Combined bending and axial	Shear
(1) Helicopter emergency landing	245/k	220,5/k	0,9 σ_c	$\frac{\text{Bending}}{\sqrt{3}}$
(2) Normal operation	176/k	147/k	0,6 σ_c	
(3) Helicopter at rest	176/k	147/k	0,6 σ_c	

Symbols

k = a material factor:

= as defined in *Pt 4, Ch 2, 1.2 Steel* for steel members

= k_a as defined in *Pt 4, Ch 2, 1.3 Aluminium* for aluminium alloy members

σ_c = yield stress, 0,2% proof stress or critical compressive buckling stress, in N/mm^2, whichever is the lesser

NOTES

1. Lower permissible stress levels may be required where helideck girders and stiffening contribute to the overall strength of the unit. Special consideration will be given to such cases.

2. When determining bending stresses in secondary structure, for compliance with the above permissible stresses, 100% end fixity may be assumed.

Table 6.5.3 Deck plate thickness calculation

Symbols	Expression	
a, *s*, *u* and *v* as defined in *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1* P_{w} = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in *Pt 4, Ch 6, 5.6 Landing area plating 5.6.1* may be taken as the combined print	$\varphi_1 = \dfrac{2v + 1,1s}{u_1 + 1,1s}$	$v_1 = v$, but ≯ s $u_1 = u$, but ≯ a
φ1 = patch aspect ratio correction factor	φ_2 = 1,0	for u ≤ (a – s)
φ2 = panel aspect ratio correction factor	$= \dfrac{1}{1,3 - \dfrac{0,3}{s}(a-u)}$	for a ≥ u > (a – s)
φ3 = wide patch load factor	$= 0,77\,\dfrac{a}{u}$	for u > a
	φ_3 = 1,0	for v < s
	$= 0,6\,\dfrac{s}{v} + 0,4$	for $1,5 > \dfrac{v}{s} > 1,0$
	$= 1,2\,\dfrac{s}{v}$	for $\dfrac{v}{s} \geq 1,5$

5.7.3 For load cases (1) and (2) in *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2* the minimum moment of inertia, $\boldsymbol{I}$, of aluminium alloy secondary structure stiffening is to be not less than:

$$I = \frac{5,25}{k_{\text{a}}} Z\, l_{\text{e}} \text{ cm}^4$$

where

Z is the required section modulus of the aluminium alloy stiffener and attached plating and k_{a} as defined in *Pt 4, Ch 2, 1.3 Aluminium*.

5.7.4 When the deck is constructed of extruded aluminium alloy sections, the scantlings will be specially considered on the basis of this Section.

5.7.5 Where a grillage arrangement is adopted for the platform stiffening, it is recommended that direct calculation procedures be used.

5.8 Bimetallic connections

5.8.1 Where aluminium alloy platforms are connected to steel structures, details of the arrangements in way of the bimetallic connections are to be submitted.

Section 6
Decks loaded by wheeled vehicles

6.1 General

6.1.1 Where it is proposed to use wheeled vehicles such as fork lift trucks and mobile cranes on deck structures, the deck plating and the supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service and the minimum gross scantlings are to comply with the requirements of *Pt 3, Ch 9, 3 Decks loaded by wheeled vehicles* of the Rules for Ships. In no case, however, are the scantlings to be less than would be required by the remaining requirements of this Chapter when the deck is considered as a weather deck or storage deck, as appropriate.

Section 7
Bulkheads

7.1 General

7.1.1 This Section is applicable to watertight and deep tank transverse and longitudinal bulkheads, watertight flats, trunks and tunnels of all units except ship units and other surface type units. Requirements are also given for non-watertight bulkheads.

7.1.2 The scantlings of bulkhead structures are to comply with:

- *Pt 10 SHIP UNITS* for ship units; and
- *Pt 4, Ch 4, 4 Surface type units* for other surface type units.

7.1.3 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

7.1.4 The number and disposition of watertight bulkheads are to be in accordance with *Pt 4, Ch 3, 5 Number and disposition of bulkheads* and the requirements of *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines* regarding watertight integrity are to be complied with.

7.1.5 The buckling requirements of *Pt 4, Ch 5, 4 Buckling strength of primary members* are also to be satisfied.

7.1.6 The height of the air and overflow pipes are to be clearly indicated on the plans submitted for approval and the load heads for scantlings are to be not less than those defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*.

7.2 Symbols

7.2.1 The following symbols are applicable to this Section:

k = higher tensile steel factor, *see Pt 4, Ch 2, 1 Materials of construction*

s = spacing of secondary stiffeners, in mm

I = inertia of stiffening member, in cm^4, *see Pt 4, Ch 3, 3 Structural idealisation*

S = spacing or mean spacing of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see Pt 3, Ch 3, 3 Hazardous areas and ventilation*

ρ = relative density (specific gravity) of liquid carried in a tank, but is not to be taken less than 1,025.

l = overall length, in metres, of the primary support member'

7.3 Watertight and deep tank bulkheads

7.3.1 The scantlings of watertight and deep tank bulkheads are to comply with the requirements of *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4* to *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.10*. Where tanks cannot be inspected

at normal periodic surveys, the scantlings derived from this Section are to be suitably increased. All tanks are to be considered as deep tanks.

7.3.2 Where bulkhead stiffeners support deck girders, transverses or pillars over, the scantlings are to satisfy the requirements of *Pt 4, Ch 6, 4 Decks*.

7.3.3 The strength of bulkheads and flats which support the ends of bracings or columns will be specially considered.

7.3.4 In way of partially filled tanks, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of the liquid in those tanks. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted, *see also Pt 4, Ch 3, 4.18 Other loads*.

Table 6.7.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004 s f \sqrt{h_4 k}$ mm but not less than 5,5 mm	$t = 0{,}004 s\, f \sqrt{\dfrac{\rho\, h_4 k}{1{,}025}}$ mm nor less than 7,5 mm
	In the case of symmetrical corrugations, *s* is to be taken as *b* or *c* in *Figure 3.3.1 Corrugation geometry* in *Pt 4, Ch 3 Structural Design*, whichever is the greater	
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s\, k\, h_4\, l_e^{\,2}}{71\, \gamma \left(\omega_1 + \omega_2 + 2\right)}$ cm^3	$Z = \dfrac{\rho\, s\, k\, h_4\, l_e^{\,2}}{22\, \gamma \left(\omega_1 + \omega_2 + 2\right)}$ cm^3
	In the case of symmetrical corrugations, *s* is to be taken as *p*, *see also* Note 2	
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \dfrac{2{,}3}{k}\, l_e Z$ cm^4
(4) Symmetrical corrugations and double plate bulkheads	Additional requirements to be complied with as detailed in *Table 6.7.2 Symmetrical corrugations and double plate bulkheads (additional requirements)*	
(5) Stringers or webs supporting vertical or horizontal stiffening		
(a) Modulus	$Z = 4{,}5 k\, h_4\, S\, l_e^2$ cm^3	$Z = 9{,}6\, \rho k\, h_4\, S\, l_e^2$ cm^3
(b) Inertia	—	$I = \dfrac{2{,}3}{k}\, l_e Z$ cm^4
Symbols		
s, S, l, k, ρ as defined in *Pt 4, Ch 6, 7.2 Symbols 7.2.1*	(c) For watertight bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater	
d_w = web depth of stiffening member, in mm	(d) For tank bulkhead stiffeners or girders, the distance from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, whichever is the greater	
$f = 1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0	l_e = effective length of stiffening member, in metres, and for bulkhead stiffeners, to be taken as $l - e_1 - e_2$, *see also Figure 6.7.1 Effective length and end constraint definitions for bulkheads*	
h_4 = load head, in metres measured vertically as follows:	*p* = spacing of corrugations as shown in *Figure 3.3.1 Corrugation geometry* in *Pt 4, Ch 3 Structural Design*	

(a) For watertight bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater	γ = 1,4 for rolled or built sections and double plate bulkheads = 1,6 for flat bars = 1,1 for symmetrical corrugations of deep tank bulkheads = 1,0 for symmetrical corrugations of watertight bulkheads
(b) For tank bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow, whichever is the greater	ω, *e* = as defined in *Table 6.7.3 Bulkhead end constraint factors*, *see also Figure 6.7.1 Effective length and end constraint definitions for bulkheads*
NOTES	
1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where the boundary bulkheads of the tanks form part of the watertight sub-division of the unit to meet damage stability requirements, *see Pt 4, Ch 3, 5 Number and disposition of bulkheads*.	4. The scantlings of all void compartments adjacent to the sea are also to comply with *Pt 4, Ch 6, 7.5 Watertight void compartments 7.5.1*.
2. For self-elevating units, the bulkhead deck is to be taken as the freeboard deck.	5. In calculating the actual modulus of symmetrical corrugations the panel width *b* is not to be taken greater than that given by *Pt 4, Ch 3, 3.2 Geometric properties of section*.
3. For column-stabilised units, the bulkhead deck is, in general, to be taken as the uppermost continuous strength deck unless agreed otherwise with LR.	6. For rolled or built stiffeners with flanges or face plates, the web thickness is to be not less than $\dfrac{d_{\text{w}}}{60\sqrt{k}}$ whilst for flat bar stiffeners the web thickness is to be not less than $\dfrac{d_{\text{w}}}{18\sqrt{k}}$

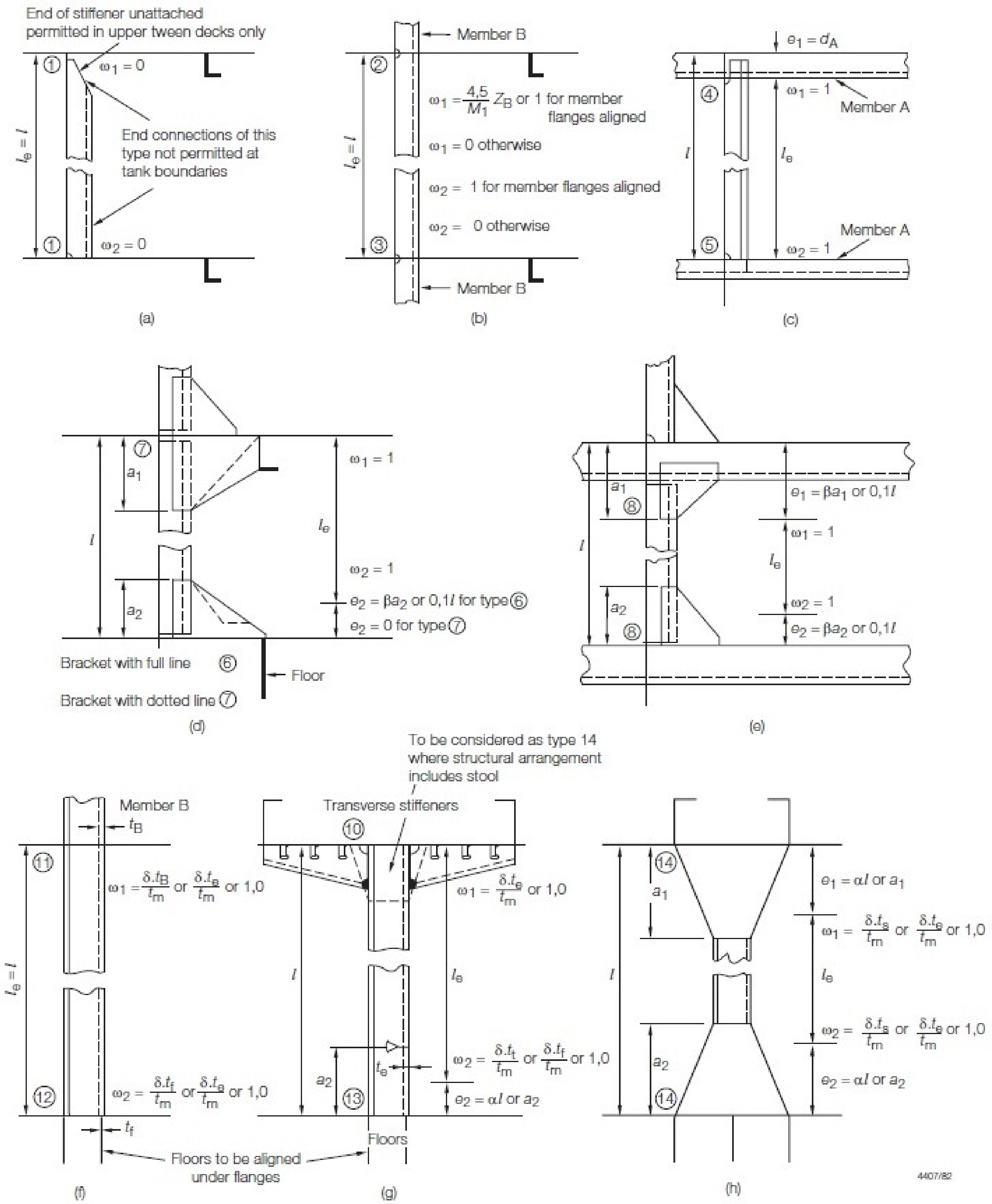


Figure 6.7.1 Effective length and end constraint definitions for bulkheads

Table 6.7.2 Symmetrical corrugations and double plate bulkheads (additional requirements)

Symbols	Type of bulkhead	Parameter	Watertight bulkheads	Deep tank bulkheads
s, *k* as defined in *Pt 4, Ch 6, 7.2 Symbols 7.2.1* *b* = panel width as shown in *Pt 4, Ch 3, 3.2 Geometric properties of section 3.2.4* in *Pt 4, Ch 3 Structural Design* *d* = depth, in mm, of symmetrical corrugation or double plate bulkhead l_{e} as defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	Symmetrically corrugated, *see also* Notes 1 and 2	$\frac{b}{t}$	Not to exceed: 85 $\sqrt{k}$ at top, and 70 $\sqrt{k}$ at bottom	Not to exceed: 70 $\sqrt{k}$ at top and bottom
			See also Note 4	
A_{w} = shear area, in cm$_2$, of webs of double plate bulkhead		*d*	—	To be not less than: 39 l_{e} mm
θ = angle of web corrugation to plane of bulkhead		θ	To be not less than 40°	
NOTES	Double plate, *see also* Note 3	$\frac{s}{t}$	Not to exceed:	75 $\sqrt{k}$ at top and 65 $\sqrt{k}$ at bottom
1. The plating thickness at the middle of span l_{e} of corrugated or double plate bulkheads is to extend not less than 0,2 l_{e} m above mid-span. 2. Where the span of corrugations exceeds 15 m, a diaphragm plate is to be arranged at about mid-span.		$\frac{d}{t_{\mathrm{w}}}$	Not to exceed:	85 $\sqrt{k}$ at top and 75 $\sqrt{k}$ at bottom
		d	—	To be not less than: 39 l_{e} mm
3. *See also Pt 4, Ch 8 Welding and Structural Details*. 4. In calculating the actual modulus of symmetrical corrugations, the panel width *b* is not to be taken greater than that given by *Pt 4, Ch 3, 3.2 Geometric properties of section*.		A_{w}	To be not less than: $\frac{0,12Z}{l_{\mathrm{e}}}$ cm^2 at top, and $\frac{0,18Z}{l_{\mathrm{e}}}$ cm^2	$\frac{0,07Z}{l_{\mathrm{e}}}$ cm^2 at top, and $\frac{0,10Z}{l_{\mathrm{e}}}$ cm^2

7.3.5 In deep tanks, fuel oil or other liquids are to have a flash point of 60°C or above (closed-cup test). Where tanks are intended for liquids of a special nature, the scantlings and arrangements will be specially considered in relation to the properties of the liquid, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.6*. For the scantlings of mud tanks, *see Pt 4, Ch 6, 7.6 Mud tanks*.

7.3.6 Where tanks are intended for the storage of oil with a flash point less than 60°C (closed-cup test) the scantlings of bulkheads are to comply with:

- *Pt 10 SHIP UNITS* for ship units.
- *Pt 4, Ch 4, 4 Surface type units* for other surface-type units.
- This Section for other unit types.

The minimum scantlings and arrangements on all units are also to comply with *Pt 3, Ch 3 Production and Storage Units*.

7.3.7 For cofferdams on units with oil storage tanks, as defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.6*, the separation of tanks and spaces are to comply with *Pt 3, Ch 3 Production and Storage Units*. Cofferdams are to be fitted between tanks as necessary, depending on the liquids stored. In general, cofferdams are to be fitted between tanks in accordance with the requirements of *Pt 4, Ch 3, 5 Number and disposition of bulkheads*.

7.3.8 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration. Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

7.3.9 Wash bulkheads or divisions are to be fitted to deep tanks as required by *Pt 4, Ch 7, 4 Watertight integrity*. The division bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the plating thickness is not to be less than 7,5 mm and the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h_4 measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than five per cent nor more than 10 per cent of the total area of the bulkhead. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

7.3.10 The scantlings of end brackets fitted to bulkhead stiffeners are, in general, to comply with *Pt 4, Ch 8 Welding and Structural Details*.

Table 6.7.3 Bulkhead end constraint factors

Type	End connection, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*			ω	*e*	μ
Rolled or built stiffeners and swedges						
1	End of stiffeners unattached or attached to plating only			0	0	—
2	Members with webs and flanges (or bulbs) in line and attached at deck or horizontal girder *See also* Note 1	Adjacent member of B of smaller modulus		The lesser of $\frac{4,5Z_B}{M_1}$ or 1,0	0	—
3		Adjacent member B of same or larger modulus		1,0	0	—
4	Bracketless connection to longitudinal member	Member A within length *l*		1,0	$\frac{d_A}{1000}$	—
5		Member A within length *l*		1,0	0	—
6	Bracketed connection	To transverse member	Bracket extends to floor	1,0	The lesser of βa or 0,1*l*	—
7			Otherwise	1,0	0	—
8		To longitudinal member		1,0	The lesser of βa or 0,1*l*	—
Symmetrical corrugations or double plate bulkheads						

9	Welded directly to deck – no bulkhead in line	No longitudinal brackets	0	0	–
10		With longitudinal brackets and transverse stiffeners supporting corrugated bulkhead	The lesser of $\dfrac{\delta\, t_{\mathrm{e}}}{t_{\mathrm{m}}}$ or 1,0	0	–
11	Welded directly to deck or girder	Bulkhead B, having same section, in line	The least of $\dfrac{\delta\, t_{\mathrm{B}}}{t_{\mathrm{m}}}$ or $\dfrac{\delta\, t_{\mathrm{e}}}{t_{\mathrm{m}}}$ or 1,0	0	–
12	Welded directly to tank top and effectively supported by floors in line with each bulkhead flange, *see also* Note 2	Thickness at bottom same as that at mid-span	The least of $\dfrac{\delta\, t_{\mathrm{f}}}{t_{\mathrm{m}}}$ or $\dfrac{\delta\, t_{\mathrm{e}}}{t_{\mathrm{m}}}$ or 1,0	0	–
13		Thickness at bottom greater than that at mid-span	The least of $\dfrac{\delta\, t_{\mathrm{f}}}{t_{\mathrm{m}}}$ or $\dfrac{\delta\, t_{\mathrm{e}}}{t_{\mathrm{m}}}$ or 1,0	The lesser of αl or a	The lesser of $\dfrac{t_{\mathrm{f}}}{t_{\mathrm{m}}}$ or $\dfrac{t_{\mathrm{e}}}{t_{\mathrm{m}}}$
14	Welded to stool efficiently supported by the unit's structure		For deep tank bulkheads 1,0 For watertight bulkheads the least of $\dfrac{\delta\, t_{\mathrm{f}}}{t_{\mathrm{m}}}$ or $\dfrac{\delta\, t_{\mathrm{e}}}{t_{\mathrm{m}}}$ or 1,0	The lesser of αl or a	$\dfrac{10 Z_{\mathrm{s}}}{M_2}$

Symbols

s, l, ρ, *k,* as defined in *Pt 4, Ch 6, 7.2 Symbols 7.2.1*	Z_{B} = section modulus, in cm$_3$, of adjacent member B	
a = height, in metres, of bracket or end stool or lowest strake of plating of symmetrically corrugated or double plate bulkheads, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	α = a factor depending on μ and determined as follows:	
d_{A} = web overall depth, in mm, of adjacent member A	where μ ≤ 1,0	α = 0
e = effective length, in metres, of bracket or end stool, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	where μ > 1,0	$\alpha = 0{,}5 - \dfrac{1}{\sqrt{2\,\mu\; + 2}}$
$h_{\mathrm{o}} = h_4$ but measured from the middle of the overall length l l_{e} , *p*, h_4 as defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*	β = a factor depending on the end bracket stiffening and to be taken as:	
t_{f} = thickness of supporting floor, in mm	1,0 for brackets with face bars directly connected to stiffener face bars 0,7 for flanged brackets 0,5 for unflanged brackets	
t_{m} , t_{e} = thickness, in mm, of flange plating of corrugation or double plate bulkhead at mid-span or end, respectively	δ = 1,0 generally	
t_{s} = thickness, in mm, of stool adjacent to bulkhead	$\delta = \dfrac{0{,}932\sqrt{k}}{\xi}$ for corrugated watertight bulkheads	

t_B = thickness, in mm, of flange plating of member B	η = lesser of 1,0 and $\frac{50 t_m \sqrt{k}}{b}$ for welded sections
Subscripts 1 and 2, when applied to ω, *e* and *a*, refer to the top and bottom ends of stiffener respectively	η = lesser of 1,0 and $\frac{60 t_m \sqrt{k}}{b}$ for cold formed sections
$M_1 = \frac{h_4 s l^2_e}{71}$ for watertight bulkheads	μ = a factor representing end constraint for symmetrical corrugation and double plate bulkheads
$= \frac{r h_4 s l^2_e}{22}$ for deep tank bulkheads	ξ = 1,0 where full continuity of corrugation webs is provided at the ends
$M_2 = \frac{h_o s l^2}{71}$ for watertight bulkheads	ξ = greater of 1,0 and (η + 0,333) where full continuity is not provided
$= \frac{\rho h_o s l^2}{22}$ for deep tank bulkheads	ω = an end constraint factor relating to the different types of end connection, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*
In the case of symmetrical corrugations *s* = *p*	
Z_s = section modulus, in cm_3, of horizontal section of stool adjacent to deck or tank top over breadth *s* or *p* (as applicable)	
All material which is continuous from top to bottom of stool may be included in the calculation	
NOTES 1. Where the end connection is similar to type 2 or 3, but member flanges (or bulbs) are not aligned and brackets are not fitted, ω = 0. 2. Where the end connection is similar to type 12 or 13, but a transverse girder is arranged in place of one of the supporting floors, special consideration will be required.	

7.4 Watertight flats, trunks and tunnels

7.4.1 The scantlings and arrangements of watertight flats, trunks and tunnels are to be equivalent to the requirements for watertight bulkheads or tanks as defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads* as appropriate. The scantlings of shaft tunnels will be specially considered. The scantlings at the crown or bottom of tanks are to comply with the requirements of *Pt 4, Ch 6, 4.3 Deck stiffening 4.3.3*.

7.4.2 Additional strengthening is to be fitted to tunnels under the heels of pillars, as necessary.

7.5 Watertight void compartments

7.5.1 In all units where watertight void compartments are adjacent to the sea, the scantlings of the boundary bulkheads are to be determined from *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*for watertight bulkheads but the scantlings are not to be less than required for tank bulkheads using the load head h_4 , measured to the maximum operating draught of the unit.

7.6 Mud tanks

7.6.1 The scantlings of mud tanks are to be not less than those required for tanks using the design density of mud. However, in no case is the relative density of wet mud to be taken as less than 2,2 unless agreed otherwise with LR.

7.7 Non-watertight bulkheads

7.7.1 The scantlings of non-watertight bulkheads supporting decks are to be in accordance with *Pt 4, Ch 6, 4.5 Deck openings 4.5.7*.

Section 8
Double bottom structure

8.1 Symbols and definitions

8.1.1 The symbols used in this Section are defined as follows:

L, T_0 and T_{T} as defined in *Pt 4, Ch 1, 5 Definitions*

B as defined in *Pt 4, Ch 1, 5 Definitions* but need not exceed B_1

B_1 = maximum distance between longitudinal bulkheads, in metres

d_{DB} = Rule depth of centre girder, in mm

d_{DBA} = actual depth of centre girder, in mm

h_{DB} = head from top of inner bottom to top of overflow pipe, in metres

h_4 = load head as defined in *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*

s = spacing of stiffeners, in mm.

8.2 General

8.2.1 In general, double bottoms need not be fitted in non-propelled units and column-stabilised units, except where required by a National Administration.

8.2.2 Where double bottoms are fitted, the scantlings are to comply with:

- *Pt 10 SHIP UNITS* for ship units.
- *Pt 4, Ch 4, 4 Surface type units* for other surface-type units.
- This Section for other unit types.

8.2.3 The requirements in this Section are, in general, applicable to double bottoms with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed the scantlings will be specially considered, but the minimum requirements of this Section are to be complied with.

8.2.4 The arrangements of drainage wells, recesses and dump valves in the double bottom will be specially considered.

8.2.5 If it is intended to dry-dock the unit, girders and the side walls of duct keels are to be continuous and the structure is to have adequate strength to withstand the forces imposed by dry-docking the unit.

8.2.6 Adequate access is to be provided to all parts of the double bottom. The edges of all holes are to be smooth. The size of the opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

8.2.7 Provision is to be made for the free passage of air and water from all parts of tank spaces to the air pipes and suctions, account being taken of the pumping rates required. To ensure this, sufficient air holes and drain holes are to be provided in all longitudinal and transverse non-watertight primary and secondary members. The drain holes are to be located as close to the bottom as is practicable, and air holes are to be located as close to the inner bottom as is practicable, *see also Pt 3, Ch 8 Process Plant Facility*.

8.3 Self-elevating units

8.3.1 When a double bottom is fitted to a self-elevating unit, the scantlings of the double bottom will be specially considered in accordance with *Pt 4, Ch 4, 3 Self-elevating units* but the general requirements of this Section are to be complied with.

8.3.2 The longitudinal extent of the double bottom will be specially considered in respect of the design and safety of the unit but it should extend as far forward and aft as is practicable. A double bottom need not be fitted in pre-load deep tanks or other wing deep tanks.

8.3.3 The depth of the double bottom at the centreline, d_{DB} , is to be in accordance with *Pt 4, Ch 6, 8.3 Self-elevating units 8.3.4* and the inner bottom is, in general, to be continued out to the unit's side in such a manner as to protect the bottom to the turn of bilge. When pre-load wing deep tanks are fitted port and starboard, the inner bottom may be terminated at the deep tank longitudinal bulkheads.

8.3.4 **The centre girder** is to have a depth of not less than that given by:

$$d_{\text{DB}} = 28B + 205\sqrt{T_{\text{T}}} \text{ mm}$$

nor less than 760 mm. The centre girder thickness is to be not less than:

$$t = (0{,}008\, d_{\text{DB}} + 4)\sqrt{k} \text{ mm}$$

nor less than 6,0 mm. The thickness may be determined using the value for d_{DB} without applying the minimum depth of 760 mm.

8.3.5 **Side girders** are to be fitted below longitudinal bulkheads. In general, one side girder is to be fitted where the breadth, *B*, exceeds 14 m and two side girders are to be fitted on each side of the centreline where *B* exceeds 21 m. Equivalent arrangements are to be provided where longitudinal bulkheads are fitted. The side girders are to extend as far forward and aft as practicable and are to have a thickness not less than:

$$t = (0{,}0075\, d_{\text{DB}} + 1)\sqrt{k} \text{ mm}$$

nor less than 6,0mm. In general, a vertical stiffener, having a depth not less than 100 mm and a thickness equal to the girder thickness, is to be arranged midway between floors.

8.3.6 *Watertight side girders* are to have a plating thickness corresponding to the greater of the following:

(a) $t = (0{,}0075\, d_{\text{DB}} + 2)\sqrt{k}$ mm, or

(b) Thickness, *t*, as for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.7 If the depth of the watertight side girders exceeds 915 mm but does not exceed 2000 mm, the girders are to be fitted with vertical stiffeners spaced not more than 915 mm apart and having a section modulus not less than:

$$Z = 5{,}41\, {d_{\text{DBA}}}^2\, h_{\text{DB}}\, s\, k \times 10^{-9} \text{ cm}^3$$

The ends of the stiffeners are to be sniped. Where the double bottom tanks are interconnected with side tanks or cofferdams, or where the depth of the girder exceeds 2000 mm, the scantlings of watertight girders are to be not less than those required for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*, and the ends of the stiffeners are to be bracketed top and bottom.

8.3.8 **Duct keels**, where arranged, are to have a thickness of side plates corresponding to the greater of the following:

(a) $t = (0{,}008\, d_{\text{DB}} + 2)\sqrt{k}$ mm, or

(b) Thickness, *t*, as for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.9 The sides of the duct keels are, in general, to be spaced not more than 2,0 m apart. Where the sides of the ducts keels are arranged on either side of the centreline or side girder, each side is, in general, to be spaced not more than 2,0 m from the centreline or side girder. The inner bottom and bottom shell within the duct keel are to be suitably stiffened. The primary stiffening in the transverse direction is to be suitably aligned with the floors in the adjacent double bottom tanks. Where the duct keels are adjacent to double bottom tanks which are interconnected with side tanks or cofferdams, the stiffening is to be in accordance with the requirements for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*. Access to the duct keel is to be by watertight manholes or trunks.

8.3.10 **Inner bottom plating** is, in general, to have a thickness not less than:

$$t = 0{,}00136\,(s + 660)\,(k^2\,L\,T_T)^{1/4} \text{ mm}$$

nor less than 6,5 mm.

8.3.11 The thickness of the inner bottom plating as determined in *Pt 4, Ch 6, 8.3 Self-elevating units 8.3.10* is to be increased by 10 per cent in machinery spaces but in no case is the thickness to be less than 7,0 mm.

8.3.12 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than that required for inner bottom plating.

8.3.13 Where the double bottom tanks are common with side tanks or cofferdams, the thickness of the inner bottom plating is to be not less than that required for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*, and the load head h_4 is to be measured to the highest point of the side tank or cofferdam.

8.3.14 Inner bottom stiffeners are in general to have a section modulus not less than 85 per cent of the Rule value for bottom shell stiffeners, *see Pt 4, Ch 6, 3.3 Self-elevating units 3.3.1*. When the inner bottom design loading is considerably less than $9{,}82T_T$ kN/m^2 (T_T tonne-f/m^2) the scantlings of the inner bottom stiffeners will be specially considered. Where the double bottom tanks are interconnected with side tanks or cofferdams, the scantlings are to be not less than those required for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*.

8.3.15 **Plate floors** are to be fitted under heavy machinery items and under bulkheads and elsewhere at a spacing not exceeding 3,8 m. The thickness of non-watertight plate floors is to be not less than:

$$t = (0{,}009\,d_{DB} + 1)\sqrt{k} \text{ mm}$$

nor less than 6,0 mm. The thickness need not be greater than 15 mm, but the ratio between the depth of the double bottom and the thickness of the floor is not to exceed 130 $\sqrt{k}$. This ratio may, however, be exceeded if suitable additional stiffening is fitted. Vertical stiffeners are to be fitted at each bottom shell stiffener, having a depth not less than 150 mm and a thickness equal to the thickness of the floors. For units of length, L, less than 90 m, the depth is to be not less than $1{,}65L$ mm, with a minimum of 50 mm.

8.3.16 **Watertight floors** are to have thickness not less than:

(a) $t = (0{,}008\,d_{DB} + 3)\sqrt{k}$ mm, or

(b) $t = (0{,}009\,d_{DB} + 1)\sqrt{k}$ mm,

whichever is the greater, but not to exceed 15 mm on floors of normal depth. The thickness is also to satisfy the requirements for deep tanks, *see Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads*, with the load head h_4 measured to the highest point of the side tank or cofferdam if the double bottom tank is interconnected with these tanks. The scantlings of the stiffeners are to be in accordance with the requirements of *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads* for deep tanks, but in no case is the modulus to be less than:

$$Z = 5{,}41\,{d_{DBA}}^2\,h_{DB}\,s\,k \times 10^{-9} \text{ cm}^3$$

Vertical stiffeners are to be connected to the inner bottom and shell stiffeners.

8.3.17 Between plate floors, transverse brackets having a thickness not less than $0{,}009\,d_{DB}$ mm are to be fitted, extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,25 m.

8.3.18 Where floors form the boundary of a sea inlet box, the thickness of the plating is to be the same as the adjacent shell, but not less than 12,5 mm. The scantlings of stiffeners, where required are, in general, to comply with *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads* for deep tanks. Sniped ends for stiffeners on the boundaries of these spaces are to be avoided wherever practicable. The stiffeners should be bracketed or the free end suitably supported to provide alignment with backing structure.

8.4 Column-stabilised, tension-leg, deep draught caisson, buoy, and sea bed-stabilised units

8.4.1 Where a double bottom is fitted in the lower hull of column-stabilised, tension-leg, deep draught caisson, buoy or sea bed-stabilised units, the scantlings of the double bottom structure will be specially considered but the general requirements of *Pt 4, Ch 6, 8.3 Self-elevating units* are to be complied with where applicable. The minimum scantlings of the double bottom structure

are to be in accordance with *Pt 4, Ch 6, 8.4 Column-stabilised, tension-leg, deep draught caisson, buoy, and sea bed-stabilised units 8.4.2*.

8.4.2 The scantlings of tank boundaries are to comply with the requirements for tank bulkheads in *Pt 4, Ch 6, 7 Bulkheads* but the load head h_4 is not to be taken less than the distance measured to T_0 . When the internal double bottom compartment is a void space the scantlings of watertight boundaries are to comply with *Pt 4, Ch 6, 7.5 Watertight void compartments 7.5.1* and *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4*.

8.4.3 The boundaries of a sea inlet box are to comply with the requirements of *Pt 4, Ch 6, 8.3 Self-elevating units 8.3.18*.

8.4.4 The strength of the bottom structures in sea bed-stabilised units is also to comply with *Pt 4, Ch 4, 2.1 General 2.1.6* .

■ *Section 9*
Superstructures and deckhouses

9.1 General

9.1.1 The term ‘erection’ is used in this Section to include both superstructures and deckhouses.

9.1.2 Erections are to comply with

- *Pt 10 SHIP UNITS* for ship units.
- *Pt 4, Ch 4 Structural Unit Types* for other surface-type units.
- This Section for other unit types.

Units with a Rule length, *L*, greater than 150 m will be specially considered.

9.1.3 The scantlings of exposed bulkheads and decks of deckhouses are generally to comply with the requirements of this Section, but increased scantlings may be required where the structure is subjected to local loadings greater than those defined in the Rules, *see also Pt 4, Ch 6, 9.1 General 9.1.6*. Where there is no access from inside the house to below the freeboard deck or into buoyant spaces included in stability calculations, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

9.1.4 The scantlings of superstructures which form an extension of the side shell or which form an integral part of the unit’s hull and contribute to the overall strength of the unit will be specially considered. The upper hull structure of column-stabilised units are to comply with *Pt 4, Ch 6, 3 Watertight shell boundaries*.

9.1.5 Any exposed part of an erection which may be subject to immersion in damage stability conditions and which could result in down flooding is to have scantlings not less than required for watertight bulkheads given in *Pt 4, Ch 6, 7 Bulkheads*.

9.1.6 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to comply with *Pt 4, Ch 3, 4 Structural design loads* and permissible stress levels are to satisfy the factors of safety given in *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in in *Pt 4, Ch 5, 2 Permissible stresses*.

9.1.7 The scantlings of erections used for helicopter landing areas are also to comply with *Pt 4, Ch 6, 5 Helicopter landing areas*.

9.1.8 For requirements relating to companionways, doors and hatches, *see Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

9.2 Symbols

9.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, T_{T} and C_{b} as defined in *Pt 4, Ch 1, 5.1 General*.

b = breadth of deckhouse, at the positions under consideration, in metres

k = higher tensile steel factor, *see Pt 4, Ch 2, 1.2 Steel*

l_{e} = effective length, in metres, of the stiffening member, deck beam or longitudinal measured between span points, *see Pt 4, Ch 3, 3.3 Determination of span point*

l_s = span, in metres, of erection stiffeners and is to be taken as the ‘tween deck or house height but in no case less than 2,0 m

s = spacing of stiffeners, beams or longitudinals, in mm

s_b = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:

(a) for 0,05L from the ends:

s_b = 610 mm or that required by *Pt 4, Ch 6, 9.2 Symbols 9.2.1*, whichever is the lesser

(b) elsewhere:

s_b = 470 + 1,67 L_2 mm but forward of 0,2*L* from the forward perpendicular s_b is not to exceed 700 mm

B_1 = actual breadth of unit at the section under consideration, measured at the weather deck, in metres

L_2 = Rule length, *L*, but need not be taken greater than 250 m

L_3 = Rule length, *L*, but need not be taken greater than 300 m

D = moulded depth of unit, in metres, to the uppermost continuous deck

X = distance, in metres, between the after perpendicular and the bulkhead under consideration. When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding 0,15*L* each, and *X* is to be measured to the mid-length of each part

α = a coefficient given in *Pt 4, Ch 6, 9.2 Symbols 9.2.1*

β =

$$1{,}0 + \left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{\left(C_b + 0{,}2\right)}\right)^2 \text{ for } \frac{X}{L} \leq 0{,}45$$

=

$$1{,}0 + 1{,}5\left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{\left(C_b + 0{,}2\right)}\right)^2 \text{ for } \frac{X}{L} \leq 0{,}45$$

C_b is to be taken not less than 0,6 nor greater than 0,8. Where the aft end of an erection is forward of amidships, the value of C_b used for determining β for the aft end bulkhead is to be taken as 0,8

γ = vertical distance, in metres, from the maximum transit waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate

δ = 1,0 for exposed machinery casings and

$\left(0{,}3 + 0{,}7\frac{b}{B_1}\right)$ elsewhere, but in no case to

be taken less than 0,475

λ = a coefficient given in *Pt 4, Ch 6, 9.2 Symbols 9.2.1*.

Table 6.9.1 Values of α

Position	α
Lowest tier – unprotected front	2,0 + 0,0083 L_3

Second tier – unprotected front	1,0 + 0,0083 L_3
Third tier and above – unprotected front All tiers – protected fronts All tiers – sides	0,5 + 0,0067 L_3
All tiers – aft end where aft of amidships	0,7 + 0,001 L_3 – 0,8 $\frac{X}{L}$
All tiers – aft end where forward of amidships	0,5 + 0,001 L_3 – 0,4 $\frac{X}{L}$

Table 6.9.2 Values of λ

Length *L* in metres	λ	Expression for λ
20	0,89	L ≤ 150 m $\lambda = \left(\frac{L}{10} e - \frac{L}{300}\right) - \left(1 - \left(\frac{L}{150}\right)^2\right)$
30	1,76	
40	2,57	
50	3,34	
60	4,07	
70	4,76	
80	5,41	
90	6,03	
110	7,16	
130	8,18	
150	9,10	
150	9,10	150 m ≤ *L* ≤ 300 m $\lambda = \frac{L}{10} e - \frac{L}{300}$
170	9,65	
190	10,08	
210	10,43	
230	10,69	
250	10,86	
270	10,98	
290	11,03	
300	11,03	
300 and above	11,03	*L* ≥ 300 m λ = 11,03

9.3 Definition of tiers

9.3.1 The first, or the lowest tier, is an erection situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier, and so on.

9.3.2 For self-elevating units where the freeboard corresponding to the required summer moulded draught for the unit can be obtained by considering the unit to have a virtual moulded depth of at least one standard superstructure height less than the Rule depth, *D*, measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in the *International Convention on Load Lines, 1966*.

9.4 Design pressure head

9.4.1 The design pressure head, *h*, to be used in the determination of erection scantlings is to be taken as:

$$h = \alpha \, \delta \, (\beta \, \lambda - \gamma) \text{ m}$$

9.4.2 In no case is the design pressure head to be taken as less than the following:

(a) Lowest tier of unprotected fronts:

minimum $h = 2{,}5 + 0{,}01 \, L_2$ m

(b) All other locations:

minimum $h = 1{,}25 + 0{,}005 \, L_2$ m

9.5 Bulkhead plating and stiffeners

9.5.1 The plating thickness, *t*, of fronts, sides and aft ends of all erections other than the sides of the superstructures where these are an extension of the side shell, is not to be less than:

$$t = 0{,}003s \sqrt{k\,h} \text{ mm,}$$

but in no case is the thickness to be less than:

(a) for the lowest tier:

$t = (5{,}0 + 0{,}01 \, L_3) \sqrt{k}$ mm,

but not less than 5,0 mm.

(b) for the upper tiers:

$t = (4{,}0 + 0{,}01 \, L_3) \sqrt{k}$ mm,

but not less than 5,0 mm.

9.5.2 The thickness of sides of forecastles, bridges and poops is to be as required by *Pt 4, Ch 4, 4 Surface type units*.

9.5.3 The modulus of stiffeners, *Z*, on fronts, sides and end bulkheads of all erections, other than the sides of superstructures where these are an extension of the side shell, is to be not less than:

$$Z = 0{,}0035 h \, s \, l_s^2 \, k \text{ cm}^3$$

9.5.4 The end connections of stiffeners are to be as given in *Pt 4, Ch 6, 9.5 Bulkhead plating and stiffeners 9.5.5*.

9.5.5 The section modulus of side frames of forecastles, bridges and poops is to be as required by *Pt 4, Ch 4, 4 Surface type units*.

Table 6.9.3 Stiffener end connections

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and of upper tiers when *L* is 160 m or greater	*See Pt 4, Ch 8 Welding and Structural Details* *See* Note
2. Front stiffeners of upper tiers when *L* is less than 160 m	May be unattached

3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted, and aft end stiffeners of after deckhouses on deck to which *D* is measured	*See Pt 4, Ch 8 Welding and Structural Details*
5. Side stiffeners of upper tiers where *L* is 160 m or greater	*See Pt 4, Ch 8 Welding and Structural Details*
6. Side stiffeners of upper tiers when *L* is less than 160 m	May be unattached
7. Aft end stiffeners except as covered by item 4	May be unattached
8. Exposed machinery and pump-room casings. Front sitffeners on amid-ship casings and all stiffeners on aft end casings which are situated on the deck to which *D* is measured	Bracketed
9. All other stiffeners on exposed machinery and pump-room casings	6,5 cm^2 of weld
NOTE Front stiffeners of lower tiers on self-elevating units are to be bracketed.	

9.6 Erections on self-elevating units

9.6.1 The scantlings of exposed ends and sides of erections are to comply with 9,5, but the additional requirements of this sub-Section are to be complied with.

9.6.2 The plating thickness, t, of exposed lower tier fronts is to be not less than:

$$t = 0{,}0036 s \sqrt{k\,h} \text{ mm}$$

but in no case is the thickness to be less than 7,0 mm.

9.6.3 The modulus of stiffeners, Z, on exposed lowest tier fronts is to be not less than:

$$Z = 0{,}0044 h\, s\, l^2_{s}\, k \text{ cm}^3$$

9.6.4 Where the exposed side of an erection is close to the side shell of the unit, the scantlings may be required to conform to the requirements for exposed bulkheads of unprotected house fronts.

9.6.5 The scantlings of jackhouses will be specially considered, but are not to be less than the scantlings that would be required for an erection at the same location.

9.6.6 The end connections of stiffeners are to be as given in *Pt 4, Ch 6, 9.5 Bulkhead plating and stiffeners 9.5.5*.

9.7 Erections on other unit types

9.7.1 Where the erection can be subjected to wave forces, the scantlings of exposed ends and sides of erections are to comply with *Pt 4, Ch 6, 9.5 Bulkhead plating and stiffeners*.

9.7.2 When the erection is not subjected to wave forces in any condition then the structure is to be suitable for the maximum design loadings but the minimum scantlings of exposed sides and ends of all erections is to be not less than:

(a) for the lowest tier:

$t = (5{,}0 + 0{,}01L)\sqrt{k}$ mm, but not less than 5,0 mm.

(b) for the upper tiers:

$t = (5{,}0 + 0{,}01L)\sqrt{k}$ mm, but not less than 5,0 mm.

9.7.3 The modulus of stiffeners, Z, of exposed sides and ends of all erections is to be not less than:

$$Z = 0{,}0035 h\, s\, l_s^2\, k \text{ cm}^3$$

where

$$h = 1{,}25 + 0{,}005L \text{ m}.$$

9.7.4 The end connections of stiffeners not subjected to wave loadings are to be as given in *Pt 4, Ch 6, 9.7 Erections on other unit types 9.7.4*.

Table 6.9.4 Other unit types stiffener end connections

Position	Attachment at top and bottom
1. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all around
2. Side stiffeners if only one tier is fitted	*See Pt 4, Ch 8 Welding and Structural Details*
3. All other stiffeners	May be unattached

9.8 Deck plating

9.8.1 In general, the thickness of erection deck plating is to be not less than that required by *Pt 4, Ch 6, 9.8 Deck plating 9.8.2*.

9.8.2 For erections not subjected to wave forces in any condition, the thickness of erection deck plating for all tiers need not exceed the requirements given in *Pt 4, Ch 6, 9.8 Deck plating 9.8.2* for third tier erections, using:

$$s_b = 470 + 1{,}67\, L_2$$

Table 6.9.5 Thickness of deck plating

Position	Thickness of deck plating, in mm		
	$L \leq 100$ m		$L > 100$ m
Top of first tier erection	$(5{,}5 + 0{,}02L)\sqrt{\frac{ks}{s_b}}$	but not less than 5,0 mm	$7{,}5\sqrt{\frac{ks}{s_b}}$
Top of second tier erection	$(5{,}0 + 0{,}02L)\sqrt{\frac{ks}{s_b}}$		$7{,}0\sqrt{\frac{ks}{s_b}}$
Top of third tier and above	$(4{,}5 + 0{,}02L)\sqrt{\frac{ks}{s_b}}$		$6{,}5\sqrt{\frac{ks}{s_b}}$
NOTE For units not subjected to wave loading, *see Pt 4, Ch 6, 9.8 Deck plating 9.8.2*.			

9.8.3 When decks are fitted with approved sheathing, the thickness derived from *Pt 4, Ch 6, 9.8 Deck plating 9.8.2* may be reduced by 10 per cent for a 50 mm sheathing thickness, or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. Inside erections the thickness may be reduced by a further 10 per cent. In no case is the deck thickness to be less than 5,0 mm.

9.8.4 The thickness, t, of forecastle deck plating is to be not less than:

$$t = (6 + 0{,}017L)\sqrt{\frac{ks}{s_b}} \text{ mm.}$$

9.9 Deck stiffening

9.9.1 The requirements for deck stiffeners in this sub- Section are applicable to both beams and longitudinals.

9.9.2 Deck stiffeners on deckhouses are to have a section modulus, Z, not less than:

$$Z = 0{,}0048\, h_6\, s\, l_e^{2}\, k \text{ cm}^3\text{, but in no case less than:}$$

$$Z = 0{,}025s \text{ cm}^3$$

where the load head, h6, is to be taken as not less than:

on first tier decks	0,9 m
on second tier	0,6 m
on third tier decks and above	0,45 m

but where the deck can be subjected to weather loading, the load, h_6 , is to be increased in accordance with the requirements given in *Pt 4, Ch 6, 2.3 Stowage rate and design heads 2.3.2*.

9.9.3 When deckhouses are subjected to specified deck loadings greater than the heads defined in *Pt 4, Ch 6, 9.9 Deck stiffening 9.9.2* or are subjected to concentrated loads, equivalent load heads are to be used, *see Pt 4, Ch 6, 9.9 Deck stiffening 9.9.2* or *Pt 4, Ch 6, 9.9 Deck stiffening 9.9.3*.

9.9.4 The section modulus of deck stiffeners on forecastles, bridges and poops is to be as required by *Pt 4, Ch 4, 4 Surface type units*.

9.10 Deck girders and transverse

9.10.1 The scantlings of deck girders and transverses on erection decks are to be in accordance with the requirements of *Pt 4, Ch 6, 4.4 Deck supporting structure 4.4.2*, using the appropriate load head, H_g , determined from *Pt 4, Ch 6, 9.9 Deck stiffening 9.9.2* or *Pt 4, Ch 6, 9.9 Deck stiffening 9.9.3*.

9.11 Strengthening at ends and sides of erections

9.11.1 Web frames or equivalent strengthening are to be arranged to support the sides and ends of large erections.

9.11.2 These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boats davits and other points of high loading.

9.11.3 Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. Erections are to be strengthened in way of davits.

9.11.4 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.11.5 At the corners of deckhouses and in way of supporting structures, attention is to be given to the connection to the deck, and doublers or equivalent arrangements should generally be fitted.

9.12 Unusual designs

9.12.1 Where superstructures or deckhouses are of unusual design, the strength is to be not less than that required by this Section for a conventional design.

9.13 Aluminium erections

9.13.1 Where an aluminium alloy complying with *Ch 8 Aluminium Alloys*of the Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in *Pt 4, Ch 6, 9.13 Aluminium erections 9.13.3*.

9.13.2 The thickness, t, of aluminium alloy members is to be not less than:

t = 2,5 + 0,022 d_{w} mm but need not exceed 10 mm

where

d_{w} = depth of the section, in mm.

9.13.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

I = 5,25$Z\, l$ cm^4

where l is the effective length of the member l_{e} or l_{s} , in metres, as defined in *Pt 4, Ch 6, 9.2 Symbols* and Z is the section modulus of the stiffener and attached plating in accordance with *Pt 4, Ch 6, 9.4 Design pressure head* and *Pt 4, Ch 6, 9.9 Deck stiffening*, taking k as 1.

Table 6.9.6 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with *Pt 4, Ch 6, 9.8 Deck plating 9.8.3*	10
Deck sheathed with wood, and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

9.13.4 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

9.13.5 For aluminium alloy helicopter decks, *see Pt 4, Ch 6, 6 Decks loaded by wheeled vehicles*.

9.14 Fire protection

9.14.1 Fire protection of aluminium alloy erections is to be in accordance with the fire safety Regulations of the appropriate National Administration, *see Pt 7, Ch 3 Fire Safety*.

9.14.2 Where it is proposed to use aluminium alloy for items or equipment in hazardous areas, incendive sparking may constitute a risk and full details are to be submitted for consideration.

Section 10
Bulwarks and other means for the protection of crew and other personnel

10.1 General requirements

10.1.1 Bulwarks or guard rails are to be provided at the boundaries of weather decks and exposed freeboard and superstructure decks and deckhouses.

10.1.2 Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by *Pt 4, Ch 6, 10.2 Construction of bulwarks* and *Pt 4, Ch 6, 10.3 Guard rail construction*. Consideration will be given to cases where this height would interfere with the normal operation of the unit.

10.1.3 The freeing arrangements in bulwarks are to be in accordance with *Pt 4, Ch 6, 10.5 Freeing arrangements*.

10.1.4 Guard rails, as required by *Pt 4, Ch 6, 10.1 General requirements 10.1.1*, are to consist of at least three courses and the opening below the lowest course is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. Where practicable, a toe plate 150 mm high is to be fitted below the lowest course. In the case of units with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

10.1.5 Satisfactory means, in the form of guard rails, lifelines, handrails, gangways, under-deck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the unit. For units with production and process plant, *see also Pt 7, Ch 3 Fire Safety*.

10.1.6 Where access openings are required in bulwarks or guard rails, they are to be fitted with suitable gates and, in general, chains are not permitted where a person could fall into the sea.

10.1.7 Where gangways on a trunk are provided by means of a stringer plate fitted outboard of the trunk side bulkheads (port and starboard), each gangway is to be a solid plate, effectively stayed and supported, with a clear walkway at least 450 mm wide, at or near the top of the coaming, with guard rails complying with *Pt 4, Ch 6, 10.1 General requirements 10.1.4*.

10.1.8 Where a National Administration has additional requirements for the protection of the crew or personnel on board, it is the Owners' responsibility to comply with all necessary Regulations.

10.2 Construction of bulwarks

10.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07L from the forward perpendicular is to be not more than 1,2 m on ship units and other surface type units and not more than 1,83 m on other unit types. Elsewhere, bulwark stays are to be not more than 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened where required to support additional loads or attachments and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

10.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses.

10.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2\, s \text{ cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, *see Pt 4, Ch 6, 10.2 Construction of bulwarks 10.2.1*

L = length of unit, in metres, but to be not greater than 100 m.

10.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the unit, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

10.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

10.2.6 When the bulwarks are required to support attachments or equipment for local operational or functional loads they are to be suitably strengthened.

10.3 Guard rail construction

10.3.1 Guard rails are, in general, to be constructed in accordance with a recognised Standard and the arrangement and spacing of guard rails are to comply with *Pt 4, Ch 6, 10.1 General requirements 10.1.4*.

10.3.2 Stanchions are to be spaced not more than 1,5 m apart and the guard rails and their supports are to be designed to withstand a horizontal loading of 0,74 kN/m applied at the top rail. The permissible stresses in association with this loading are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (a) in *Pt 4, Ch 5, 2 Permissible stresses*.

10.3.3 The stanchions and stays are to be supported by suitable under-deck stiffening.

10.3.4 When guard rails are required to support attachments for local operational or functional loads they are to be suitably strengthened.

10.4 Helicopter landing area

10.4.1 Safety nets are to be installed around the deck landing area, extending at least 1500 mm out from the perimeter. The netting is to be of approved material and of a flexible nature.

10.4.2 The safety net is to be supported at its outer edge and intermediate supports are to be spaced about 1,9 m apart. The supports are to be designed to withstand a concentrated load of 1,3 kN applied at any point on the supports. The permissible stresses are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (a) in *Pt 4, Ch 5, 2 Permissible stresses*.

10.5 Freeing arrangements

10.5.1 In general, surface type oil storage units are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

10.5.2 For self-elevating units and on ship units and other surface type units, except where the additional requirements of *Pt 4, Ch 6, 10.5 Freeing arrangements 10.5.1* apply, the requirements of *Pt 4, Ch 6, 10.5 Freeing arrangements 10.5.3* to *Pt 4, Ch 6, 10.5 Freeing arrangements 10.5.18* are applicable.

10.5.3 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

10.5.4 The minimum freeing area on each side of the unit, for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the International Convention on Load Lines, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less: area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m: area required = $0,07l$ m^2

NOTE

l need not be taken greater than $0,7L_L$, where L_L is the load line length of the unit in accordance with the International Convention on Load Lines, 1966.

10.5.5 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

10.5.6 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 10.5.4.

10.5.7 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

10.5.8 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

10.5.9 In units with no sheer, the freeing area as calculated from *Pt 4, Ch 6, 10.5 Freeing arrangements 10.5.4* is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

10.5.10 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered, but in general need not exceed 10 per cent of the bulwark area.

10.5.11 Where it is not practical to provide sufficient freeing port area in the bulwark, credit can be given for bollard and fairlead openings where these extend to the deck.

10.5.12 Where a unit fitted with bulwarks has a continuous trunk or coamings, the requirements of *Pt 4, Ch 6, 10.5 Freeing arrangements 10.5.1* are to be complied with.

10.5.13 Where a deckhouse has a breadth less than 80 per cent of the beam of the unit, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam of the unit, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the unit, this arrangement is considered as two wells, before and abaft the deckhouse.

10.5.14 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

10.5.15 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck plant, etc. in which water may be shipped and trapped. Deck equipment is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

10.5.16 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

10.5.17 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

10.5.18 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port.

10.6 Deck drainage

10.6.1 Adequate drainage arrangements by means of scuppers are to be fitted as required by *Pt 4, Ch 7, 10 Scuppers and sanitary discharges*.

■ *Section 11*
Topside to hull structural sliding bearings

11.1 General

11.1.1 This Section covers the minimum technical requirements for the design, engineering, fabrication, assembly, inspection and testing of resilient bearing pads used as support interface between topside modules and the floating offshore installation.

11.1.2 Module bearing support arrangements are to be designed to ensure the effects of vessel deformations due to global hogging, sagging and torsion on the topside structure are minimised while moment transfer from the topside modules to the hull structure is kept to a minimum. In general this needs only to be considered for topsides modules where the support spacing is greater than three or more transverse frames.

11.2 Definitions, symbols and nomenclatures

11.2.1 For definitions, symbols and nomenclatures, *see* EN 1337 parts 1, 2, 3, 5 and 8 to 11.

11.3 References

EN 1337-1:2000, *Structural bearings – Part 1: General design rules.*

EN 1337-2:2004, *Structural bearings – Part 2: Sliding elements.*

EN 1337-2:2004, *Structural bearings – Part 3: Elastomeric bearings.*

EN 1337-8, *Structural bearings – Part 8: Guide bearings and restrain bearings.*

EN 1337: *Structural bearings – Part 5: European Standard, Construction standardisation: Pot bearing.*

EN 1337-9:1997, *Structural bearings – Part 9: Protection.*

EN 1337-10; *Structural bearings – Part 10: Inspection and maintenance.*

EN 1337-11; *Structural bearings – Part 11: Transport, storage and installation.*

Euro-code 3 — *Design of steel structures – Part 2: Steel bridge.*

BS 5400 1984: *Steel, concrete and composite bridges – Part 9: Bridge bearing.*

AASHTO/NSBA G9.1 – 2004, 2004, *Steel Bridge Bearing Design and Detailing Guidelines.*

11.4 General principle

11.4.1 **Function and types**. The bearings are located at the interface between the topside modules and the hull, their function being to minimise the structural interactions of the two bodies. Particularly, they shall reduce the bending moments in the hull module support frames as well as the tension, compression and torsion in the module primary girders. Additionally, fatigue effects will be significantly reduced on both module support frames and modules.

11.4.2 The focus of this Section is on elastomeric bearing pads which are extensively used in floating offshore installations. The bearings covered in this Section are shown in cases 1.1 to 1.8 of Table 1 of EN 1337-1.

11.5 Displacements

11.5.1 **Hull deformations and deflections**. The hull is subject to deformations and deflections resulting from:

- Longitudinal and transverse hull expansion and contraction.
- Longitudinal bending producing hogging and/or sagging.
- Axial torsion.

Hull hogging and sagging result in relative movement between the topside module, at the support nodes, and the module support frames. These relative movements may be caused by a combination of the following factors:

- Temperature variation between hull construction and hull operational conditions.
- Waves/environmental conditions.
- Variations to the distribution of topside and cargo loads along the vessel.

11.5.2 **The effect of displacement on bearings.**Horizontal displacements will induce rubber strain in elastomeric bearings, and will induce sliding upon PTFE/steel surfaces for pot bearings, while vertical displacements will induce compression or tension in both types. These effects must be considered in line with the bearing material's shear, tension and compression properties.

11.5.3 **Rotations for bearing design.** In the absence of detailed analysis, the bearings are to be designed for a minimum rotation of +/-0,5 degrees about both horizontal axes to ensure topside members satisfy the allowable deflection criterion of 1:300.

11.6 Serviceability, maintenance and protection

11.6.1 Bearings under topside structures may be exposed to dirt, debris, oil and moisture that promote corrosion and deterioration. As a result, these bearings should be designed and installed to minimise environmental damage and to allow easy access for inspection. The service demands on bearings are very severe and result in a service life that is typically shorter than that of other structural elements. Therefore, allowance for bearing replacement should be given consideration in the design process and, where possible, lifting locations should be provided to facilitate removal and re-installation of bearings without damaging the structure. *See* EN 1337-9, 10 and 11 for specifications.

11.7 Additional requirements

11.7.1 **Design life**. The module bearings are required to be designed for the same service life as the module structures. The supplier of bearing material is to provide adequate evidence to support the design life of the bearings under the specified project's conditions.

11.7.2 **Environmental conditions**. The module bearings shall withstand the following environmental conditions:

- Air temperature.
- Humidity.
- Solar radiation.
- Flare radiation.

- Hydrocarbon/cryogenic spills.
- Salt-water spray.

The bearings could come into contact with miscellaneous hydrocarbons due to leakages occurring on the process equipments located on the modules. The supplier shall consider this potential event and ensure the proposed solution and supplied products do not jeopardise structural integrity or satisfactory system performance over the design life, in the event that this potential condition occurs.

However, bearing pads are not designed for blast, fire or cryogenic spills events. If necessary, a protection of bearing pads will be designed to ensure their integrity.

Passive fire protection of the bearings may be considered to protect pads against fire events.

11.7.3 Modules are to be constrained against excessive movement with lateral restraints, for example, horizontal stoppers for sliding bearings. Modules are also to be constrained against uplift unless it can be confirmed that uplift cannot occur. Consideration should be given to restricting the number of longitudinal supports to two to prevent transfer of vertical displacement of the hull to the module.

11.8 Bearing selection

11.8.1 Bearing selection is influenced by many factors, including loads, geometry, maintenance, available clearance, displacement, rotation, deflection, availability, policy, designer preference, construction tolerances and cost. In general, vertical displacements are restrained, rotations are allowed to occur as freely as possible, *see Pt 4, Ch 6, 11.5 Displacements 11.5.3*, and horizontal displacements may be either accommodated or restrained. The reaction loads on each bearing are to be in accordance with the topside structural analysis and are to account for the worst scenario loading condition, taking the relative stiffness between the topsides and hull structure into account in the analysis, as appropriate.

11.8.2 Typically, steel stoppers are used with elastomeric bearings to transfer horizontal forces from topside to the substructure. The load transfer system between bearing plates and stoppers shall be carefully designed in order to minimise impact effects.

11.9 Elastomer

11.9.1 The shear stiffness of the bearing is its most important property because it affects the forces transmitted between the superstructure and substructure. Elastomers are flexible under shear and uniaxial deformation, but they are very stiff against volume changes. This feature makes possible the design of a bearing that is flexible in shear but stiff in compression.

11.9.2 Only neoprene for plain elastomeric bearing pads and steel-reinforced elastomeric bearings is recommended. All elastomers are visco-elastic, non-linear materials and, therefore, their properties vary with strain level, rate of loading and temperature. Bearing manufacturers evaluate the materials on the basis of international rubber hardness degrees (IRHD). However, this parameter is not considered to be a good indicator of the shear modulus 'G'. The shear modulus 'G' should not be taken less than 0,7 MPa (an IRHD not less than 50 or 55).

11.10 Fatigue

11.10.1 EN 1337 provides only test and design methods for repeated compression loadings. These should be followed in detail.

11.11 Detailing

11.11.1 Care should be taken for design of load transfer in fixed and sliding bearings. Sliding bearings should be designed according to EN1337-2. Maximum deflections under each loading case should be calculated considering non-linear behaviour. No gaps between bearing plates and stoppers are allowed. For common details, *see Steel Bridge Bearing Design and Detailing Guidelines*, AASHTO/NSBA G9.1 – 2004.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter gives the minimum classification requirements for watertight and weathertight integrity and load line application.

1.1.2 The requirements for intact and damage stability and the assignment of load lines are to be in accordance with *Pt 1, Ch 2, 1 Conditions for classification*.

1.1.3 The requirements in this Chapter may be modified where necessary to take into account the requirements of the appropriate National Administration responsible for the intact and damage stability of the unit.

1.1.4 For the purpose of this Chapter, the basic types of units are those defined in the *International Convention on Load Lines*, 1966 (hereinafter referred to as the Load Line Convention), *see also Pt 3, Ch 11, 1.1 Application* of the Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships).

1.2 Plans to be submitted

1.2.1 The following plans are to be submitted for approval:

- Deck drainage, scuppers and sanitary discharges.
- Ventilators and air pipes (including closing appliances).
- Watertight doors and hatch covers (internal and external) showing scantlings, coamings and closing appliances.
- Weathertight doors and hatch covers showing scantlings, coamings and closing appliances.
- Windows and side scuttles.
- Schematic diagrams of local and remote control of watertight and weathertight doors and hatch covers and other closing appliances.
- Location of control rooms.
- Freeing arrangements.

1.2.2 The following plans are to be submitted for information:

- General arrangement.
- Arrangement plan indicating the defined watertight boundaries of spaces included in the buoyancy.
- Arrangement plans of watertight doors and hatches.
- Details of intact and worst damage stability waterlines shown in elevations and plan views.

- Freeboard plan showing the maximum design operating draughts in accordance with Load Line Regulations and indicating the position of all external openings and their closing appliances.
- Location of down flooding openings.
- Trim and stability booklet, *see Pt 1, Ch 2 Classification Regulations*.

■ *Section 2* **Definitions**

2.1 Freeboard deck

2.1.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part, and below which all openings in the sides of the unit are fitted with permanent means of watertight closing. For semi-submersible units, *see also Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.4*.

2.2 Freeboard

2.2.1 Freeboard is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line.

2.3 Weathertight

2.3.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the unit in any sea conditions.

2.3.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

2.4 Watertight

2.4.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

2.4.2 Generally, all openings below the freeboard deck in the outer shell boundaries and in main watertight decks and bulkheads are to be fitted with permanent means of watertight closing.

2.4.3 When the Rules require closing appliances with closely bolted covers, the pitch of the securing bolts is not to exceed five diameters.

2.5 Position 1 and Position 2

2.5.1 For the purpose of Load Line conditions of assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 – Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 L_{L} .

Position 2 – Upon exposed superstructure decks abaft the forward 0,25 L_{L} .

where

L_{L} = the load line length in accordance with the *International Convention on Load Lines, 1966*.

2.5.2 The application to column-stabilised units will be specially considered, *see Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.4*.

2.6 Damage waterline

2.6.1 The damage waterline is the final equilibrium waterline after damage defined in the applicable stability Regulations, *see Pt 4, Ch 7, 1.1 Application 1.1.2*.

2.7 Intact stability waterline

2.7.1 The intact stability waterline is the most severe inclined waterline to satisfy the range of intact stability defined in the applicable stability Regulations, *see Pt 4, Ch 7, 1.1 Application 1.1.2*.

2.8 Down flooding

2.8.1 Down flooding means any flooding of the interior of any part of the buoyant structure of a unit through openings which cannot be closed watertight or weathertight, as appropriate, in order to meet the intact or damage stability criteria or which are required for operational reasons to be left open.

2.8.2 The down flooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

2.8.3 Intact stability is to comply with *Pt 1, Ch 2, 1 Conditions for classification*.

■ *Section 3*
Installation layout and stability

3.1 Control rooms

3.1.1 Control rooms essential for the safe operation of the unit in an emergency are to be situated above zones of immersion after damage, as high as possible and as near a central position on the unit as is practicable. The requirements for the central ballast control station on column-stabilised units are to be in accordance with *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units*

3.2 Damage zones

3.2.1 The extent of defined damage is to be in accordance with the applicable damage stability Regulations.

3.2.2 All piping, ventilation ducts and trunks, etc. should, where practicable, be situated clear of the defined damage zones. When piping, ventilation ducts and trunks, etc. are situated within the defined extent of damage, they are to be assumed damaged and positive means of closure are to be provided at watertight subdivisions to preclude progressive flooding of other intact spaces, *see also Pt 5, Ch 13, 2 Construction and installation* of the Rules for Ships.

3.2.3 In addition to the defined damages referred to in *Pt 4, Ch 7, 3.2 Damage zones 3.2.1*, compartments with a boundary formed by the bottom shell of the unit are to be considered flooded individually unless agreed otherwise with LR.

■ *Section 4*
Watertight integrity

4.1 Watertight boundaries

4.1.1 All units are to be provided with watertight bulkheads, decks and flats to give adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. In all cases, the plans submitted are to clearly indicate the location and extent of the bulkheads. In the case of column-stabilised drilling units, the scantling of the watertight flats and bulkheads are to be made effective to that point necessary to meet the requirements of damage stability and are to be indicated on the appropriate plans.

4.1.2 The number and disposition of watertight bulkheads are to comply with *Pt 4, Ch 3, 5 Number and disposition of bulkheads*.

4.1.3 The strength of watertight subdivisions are to comply with *Pt 4, Ch 6, 7 Bulkheads*.

4.1.4 Ship units and other surface type units are to be fitted with a collision bulkhead in accordance with *Pt 3, Ch 3, 4.2 Collision bulkhead*of the Rules for Ships.

4.2 Tank boundaries

4.2.1 Deep tanks for fresh water, fuel oil or any other tanks which are not normally kept filled in service are, in general, to have wash bulkheads or divisions.

4.2.2 Tank bulkheads and watertight divisions are to have adequate strength for the maximum design pressure head in normal operating and damage conditions and the scantlings are to comply with *Pt 4, Ch 6, 7 Bulkheads*.

4.3 Boundary penetrations

4.3.1 Where internal boundaries are required to be watertight to meet damage stability requirements, the number of openings in such boundaries is to be reduced to the minimum compatible with the design and proper working of the unit.

4.3.2 Where piping, including air and overflow pipes, ventilation ducts, shafting, electric cable runs, etc. penetrate watertight boundaries, arrangements are to be made to ensure the watertight integrity of the boundary. Details of the arrangements are to be submitted for approval.

4.3.3 No openings such as manholes, watertight doors, pipelines or other penetrations are to be cut in the collision bulkhead of ship units and other surface type units, except as permitted by *Pt 5, Ch 13, 3 Drainage of compartments, other than machinery spaces* and *Pt 5, Ch 13, 4 Bilge drainage of machinery spaces* of the Rules for Ships.

4.3.4 Where pipelines or ducts serve more than one compartment, satisfactory arrangements are to be provided to preclude the possibility of progressive flooding through the system to other spaces in the event of damage, *see also Pt 4, Ch 7, 3.2 Damage zones*.

4.3.5 Where piping systems and ventilation ducts are designed to watertight standards and are suitable for the maximum design pressure head in damage conditions, they are to be provided with valves at the boundaries of each watertight compartment served.

4.3.6 Ventilation ducts which are of non-watertight construction are to be provided with valves where they penetrate watertight subdivision boundaries.

4.3.7 Where valves are provided at watertight boundaries to maintain watertight integrity in accordance with *Pt 4, Ch 7, 4.3 Boundary penetrations 4.3.5* and *Pt 4, Ch 7, 4.3 Boundary penetrations 4.3.6*, these valves are to be capable of being operated from a pump-room or other normally manned space, a weather deck, or a deck which is above the final waterline after flooding. In the case of a column-stabilised unit, this would be the central ballast control station. Valve position indicators should be provided at the remote control station, weather deck or a normally manned space.

4.3.8 For self-elevating units, the ventilation system valves required to maintain watertight integrity should be kept closed when the unit is afloat. Necessary ventilation in this case should be arranged by alternative approved methods.

4.4 Internal openings related to damage stability

4.4.1 The requirements for the operation, alarm displays and controls of watertight doors and hatch covers and other closing appliances are given in *Pt 7, Ch 1, 9 Riser systems*.

4.4.2 Internal access openings fitted with appliances to ensure watertight integrity, are to comply with the following:

(a) Watertight doors and hatch covers which are used during the operation of the unit while afloat may normally be open, provided the closing appliances are capable of being remotely controlled from a damage central control room on a deck which is above any final waterline after flooding and are also to be operable locally from each side of the bulkhead. Open/shut indicators are to be provided in the control room showing whether the doors are open or closed. In addition, remotely operated doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors with audible alarm. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimising the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It shall be possible to open/close the door by hand at the door itself from both sides.

(b) Doors or hatch covers in self-elevating units or doors placed above the deepest load line draft in column-stabilised and surface units, which are normally closed while the unit is afloat may be of the quick acting type and should be provided with an alarm system (e.g. light signals) showing personnel both locally and at the central ballast control station whether the doors or hatch covers in question are open or closed. A notice should be affixed to each such door or hatch cover stating that it is not to be left open while the unit is afloat.

(c) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum design water pressure head of the watertight boundary under consideration.

4.4.3 Internal openings fitted with appliances to ensure watertight integrity, which are to be kept permanently closed while afloat, are to comply with the following:

(a) A notice to the effect that the opening is always to be kept closed while afloat is to be attached to the closing appliances in question.
(b) Opening and closing of such closing appliances are to be noted in the unit's logbook, or equivalent.
(c) Manholes fitted with gaskets and closely bolted covers need not be dealt with as under *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.3*.
(d) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum water pressure head of the watertight boundary under consideration.

4.5 External openings related to damage stability

4.5.1 Where watertight integrity is dependent on external openings which are used during the operation of the unit while afloat, they are to comply with the following:

(a) The lower edge of openings of air pipes (regardless of their closing appliances) is to be above the final equilibrium damage waterline including wind heel effects.
(b) The lower edge of ventilator openings, doors and hatches with manually operated means of weathertight closures is to be above the final equilibrium damage waterline including wind heel effects.
(c) Openings such as manholes, fitted with gaskets and closely bolted covers, and side scuttles and windows of the non-opening type with inside hinged deadlights which are fitted with appliances to ensure watertight integrity, may be submerged. Such openings are not allowed to be fitted in the column of stabilised units.
(d) Scuppers and discharges are to be fitted with closing appliances, *see Pt 4, Ch 7, 10.1 General*.
(e) Where flooding of chain lockers or other buoyant volumes may occur, the openings to these spaces should be considered as downflooding points.

4.5.2 Where watertight integrity is dependent upon external openings which are permanently closed during the operation of the unit while afloat, such openings are to comply with the requirements of *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.3*.

4.5.3 External watertight doors and hatch covers of limited size which are used while afloat may be accepted below the worst damage waterline, including wind heel effects, provided they are on or above the freeboard deck and the closing appliances comply with the requirements of *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.2* and *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.2*.

4.6 Strength of watertight doors and hatch covers

4.6.1 The symbols used in this sub-Section are as follows:

d = distance between securing devices, in metres

f_1 = $1{,}1 - \frac{s}{2500 l_s}$ but not greater than 1

h_D = design pressure head, in metres, measured vertically from the bottom of the door to the worst damage waterline plus 5 m

k = higher tensile steel factor as defined in *Pt 4, Ch 2, 1.2 Steel*

l_s = span of stiffener between support points, in metres

s = spacing of stiffeners, in mm

P_I = packing line pressure along edges, in N/cm (kgf/cm), but not less than 50 (5,1).

4.6.2 Closing appliances for internal and external openings are to have scantlings in accordance with this sub- Section and are to satisfy the requirements of *Pt 4, Ch 7, 4.4 Internal openings related to damage stability* and *Pt 4, Ch 7, 4.5 External openings related to damage stability* respectively.

4.6.3 In general, watertight closing appliances are to be designed to withstand the design pressure head from both sides of the appliance unless the mode of failure based on the damage stability criteria can only result in one-sided pressure loading.

4.6.4 The thickness of plating, t, subjected to lateral pressure in damage conditions is to be not less than:

$t = 0{,}0048 s\, f_1 \sqrt{h_D k}$ mm but not less than 8 mm.

4.6.5 The section modulus, z, of panel stiffeners fitted in one direction and edge stiffeners is not to be less than:

$z = 0{,}0065 s\, k\, h_D\, l_s^2$ cm^3 but not less than 15 cm^3

The section modulus of secondary panel stiffeners may also be determined from the above formula, but doors with stiffeners designed as grillages will be specially considered.

4.6.6 The moment of inertia, I, of edge stiffeners is in general not to be less than:

$I = 0{,}8\, P_I\, d^4$ cm^4 ($8\, P_I\, d^4$ cm^4)

4.6.7 Securing devices for closing appliances are to be designed for water pressure acting on the opposite side of the appliance to which they are positioned, *see also Pt 4, Ch 7, 4.6 Strength of watertight doors and hatch covers 4.6.3*.

4.6.8 The strength of the bulkhead and deck framing in way of watertight closing appliances is to comply with the requirements of *Pt 4, Ch 6, 7 Bulkheads*.

4.6.9 Watertight closing appliances are to be hydraulically tested in accordance with the requirements of *Pt 3, Ch 1, 8.3 Trial trip and operational tests 8.3.1* in *Pt 3, Ch 1, 8 Inspection and workmanship* of the Rules for Ships. In general, the test is to be carried out before the appliance is fitted to the unit. The test pressure is to be applied separately to both sides of the appliance, *see also Pt 4, Ch 7, 4.6 Strength of watertight doors and hatch covers 4.6.3*.

4.6.10 After installation in the unit, watertight closing appliances are to be hose tested in accordance with the requirements of *Pt 3, Ch 1, 8.3 Trial trip and operational tests 8.3.1* in *Pt 3, Ch 1, 8 Inspection and workmanship* of the Rules for Ships, and functional tests are to be carried out to verify the satisfactory operation of the appliance, its control and alarm functions, as required by*Pt 7, Ch 1, 9 Riser systems*.

4.7 Weathertight integrity related to stability

4.7.1 Any opening, such as an air pipe, ventilator, ventilation intake or outlet, non-watertight sidescuttle, small hatch, door, etc. having its lower edge submerged below a waterline associated with the zones indicated in (a) or (b), is to be fitted with a weathertight closing appliance to ensure the weathertight integrity, when:

(a) A unit is inclined to the range between the first intercept of the right moment curve and the wind heeling moment curve and the angle necessary to comply with the requirements of *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* during the intact condition of the unit while afloat; and

(b) A column-stabilised unit is inclined to the range:

- (i) Necessary to comply with the requirements of *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability 4.7.1* and *Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.6* and with a zone measured 4,0 m perpendicularly above the final damaged waterline per *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* Code referred to *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability 4.7.1*, and
- (ii) Necessary to comply with the requirements of *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)*.

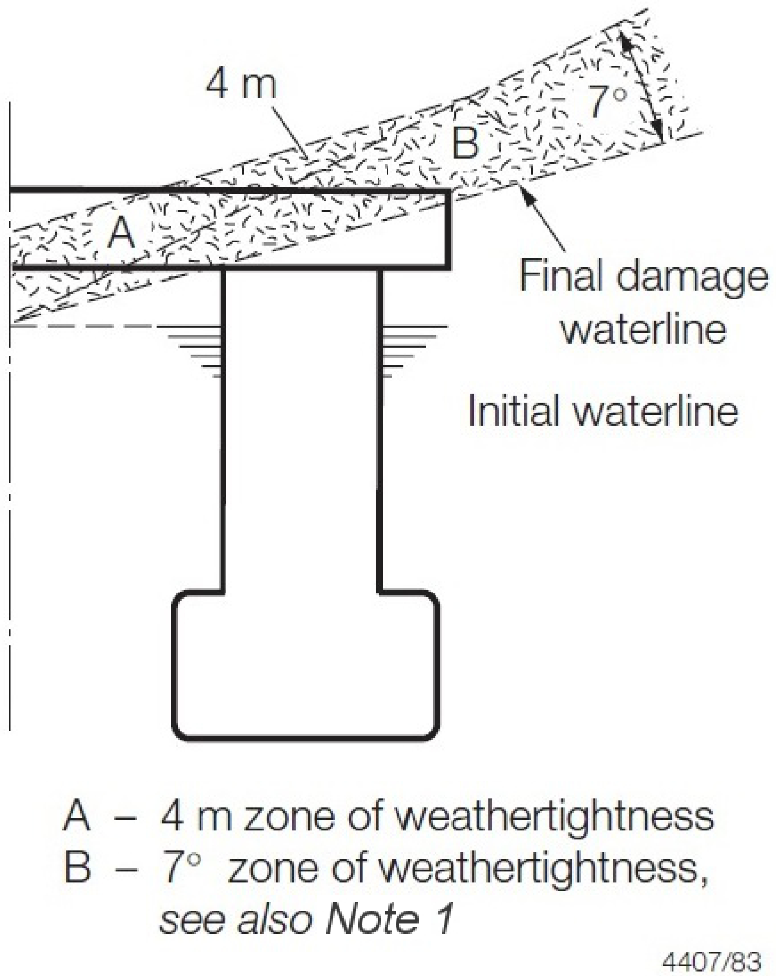


Figure 7.4.1 Minimum weathertight integrity requirements for column-stabilised and tension-leg units

4.7.2 External openings fitted with appliances to ensure weathertight integrity, which are kept permanently closed while afloat, are to comply with the requirements of *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.3* and *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.3*.

4.7.3 External openings fitted with appliances to ensure weathertight integrity, which are secured while afloat are to comply with the requirements of *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.2* and *Pt 4, Ch 7, 4.4 Internal openings related to damage stability 4.4.2* .

Section 5
Load lines

5.1 General

5.1.1 Any unit to which a load line is required to be assigned under the applicable terms of the Load Line Convention is to be subject to compliance with the Convention, *see Pt 4, Ch 7, 1.1 Application 1.1.2*. For semi-submersible and sel-felevating units, *see also Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units* and *Pt 4, Ch 7, 5.3 Self-elevating units* respectively.

5.1.2 The requirements of the Load Line Convention, with respect to weathertightness and watertightness of decks, superstructures, deckhouses, doors, hatchway covers, other openings, ventilators, air pipes, scuppers, inlets and discharges, etc. are taken as a basis for all units in the afloat conditions.

5.1.3 The requirements for hatchways, doors and ventilators are dependent upon the position on the unit as defined in *Pt 4, Ch 7, 2.5 Position 1 and Position 2*.

5.1.4 Units which cannot have freeboard computed by normal methods laid down by the Load Line Convention will have the permissible draughts determined on the basis of meeting the applicable intact stability, damage stability and structural requirements for transit and operating conditions while afloat. In no case is the draught to exceed that permitted by the Load Line Convention, where applicable.

5.1.5 All units are to have load line marks which designate the maximum permissible draught when the unit is in the afloat condition. Such markings are to be placed at suitable visible locations on the structure, to the satisfaction of LR. These marks, where practicable, are to be visible to the person in charge of mooring, lowering or otherwise operating the unit.

5.2 Column-stabilised units and tension-leg units

5.2.1 Load lines for column-stabilised and tension-leg units are to be based on the following:

- The strength of the structure.
- The air gap between the maximum operating waterline and the bottom of the upper hull structure.
- The intact and damage stability requirements.

5.2.2 The conditions of assignment are to be based on the requirements of the Load Line Convention. The Regulations of the relevant National Administration are also to be complied with, *see Pt 4, Ch 7, 1.1 Application 1.1.2*.

5.2.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc. in exposed positions and all closing appliances are to be determined by consideration of both intact and damage stability requirements.

5.2.4 The freeboard deck and reference deck from which the air gap is measured, is normally taken as the lowest continuous deck exposed to weather and sea, and which has permanent means of closing and below which all openings are watertight and permanently closed at sea.

5.2.5 Side scuttles and windows, including those of non-opening type, or other similar openings, are not to be fitted below the freeboard deck, as defined in *Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.4*.

5.2.6 In addition to the stability requirements in *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability*, the upper deck and the boundaries of the enclosed upper hull structure between the upper deck and the freeboard deck are to be made weathertight.

5.2.7 Special consideration will be given to the position of openings which cannot be closed in emergencies, such as air intakes for emergency generators.

5.3 Self-elevating units

5.3.1 Load lines and conditions of assignment for self-elevating units when afloat in transit conditions will be subject to the applicable terms of the Load Line Convention. A load line, where assigned, is not applicable to self-elevating units when resting on the sea bed, or when lowering to or raising from such position. The Regulations of the relevant National Administration are also to be complied with, *see Pt 4, Ch 7, 1.1 Application 1.1.2*.

5.3.2 Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.3.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc. in exposed positions and all closing appliances are also to be determined by consideration of both intact and damage stability requirements.

5.4 Ship units and surface type units

5.4.1 Ship units and surface type units are to comply with the requirements of *Pt 4, Ch 7, 5.1 General 5.1.1*. Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.5 Sea bed-stabilised units

5.5.1 When afloat in transit conditions, sea bed-stabilised units are to comply with the requirements of *Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units* and *Pt 4, Ch 7, 5.3 Self-elevating units* as applicable.

5.6 Deep draught caissons and buoy units

5.6.1 The weathertight integrity of units which are not subject to the requirements of the Load Line Convention will be specially considered on the basis of *Pt 4, Ch 7, 5.7 Weathertight integrity* and the requirements for both intact and damage stability. *See also Pt 4, Ch 7, 1.1 Application*.

5.7 Weathertight integrity

5.7.1 Closing arrangements for shell, deck and bulkhead openings and the requirements for ventilators, air pipes and overboard discharges, etc. are to comply with *Pt 4, Ch 7, 6 Miscellaneous openings* to *Pt 4, Ch 7, 10 Scuppers and sanitary discharges*.

5.7.2 The requirements of this Chapter conform, where relevant, with those of the Load Line Convention. Reference should also be made to any additional requirements of the National Authority of the country in which the unit is to be registered and to the appropriate Regulations of the Coastal State Authority in the area where the unit is to operate.

5.7.3 The closing appliances are, in general, to have a strength at least corresponding to the required strength of that part of the hull in which they are fitted.

5.7.4 The requirements for closing appliances of hatches, doors, ventilators, air pipes, etc. and their associated coamings, situated at such a height as will not constitute a danger to the weathertightness of the unit, will be specially considered.

5.7.5 In all areas where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

■ *Section 6*
Miscellaneous openings

6.1 Small hatchways on exposed decks

6.1.1 The requirements of *Pt 3, Ch 11, 6.1 Small hatchways on exposed decks* of the Rules for Ships are to be complied with, as applicable.

6.1.2 In general, small hatch cover scantlings and securing devices are to be in accordance with *Pt 4, Ch 7, 6.1 Small hatchways on exposed decks 6.1.3* or with an acceptable standard.

6.1.3 Hatch covers of a greater size than those defined in *Pt 4, Ch 7, 6.1 Small hatchways on exposed decks 6.1.3* will have their scantlings and closing arrangements specially considered.

Table 7.6.1 Hatch cover scantlings

Size of hatch (mm)	Plate (mm)	Stiffeners	Toggles
600 x 600	8,0	—	4
760 x 760	8,0	—	6

925 x 925	8,0	75 x 7,5 mm flat bar	7
1220 x 1220	10,0	75 x 7,5 mm flat bar	8

6.1.4 When applicable, large hatch covers are to comply with the requirements of *Pt 3, Ch 11 Closing Arrangements for Shell, Deck and Bulkheads* of the Rules for Ships.

6.1.5 Small hatches, including escape hatches, are to be situated clear of any obstructions.

6.1.6 The height and scantlings of coamings are to be in accordance with *Pt 4, Ch 7, 6.3 Hatch coamings*.

6.2 Hatchways within enclosed superstructures or 'tween decks

6.2.1 The requirements of *Pt 4, Ch 7, 6.1 Small hatchways on exposed decks* are to be complied with, where applicable.

6.2.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.3 Hatch coamings

6.3.1 The height of coamings of hatchways situated in Positions 1 and 2 closed by steel covers fitted with gaskets and clamping devices are to be not less than:

- 600 mm at Position 1;
- 450 mm at Position 2.

6.3.2 Lower heights than those defined in *Pt 4, Ch 7, 6.3 Hatch coamings 6.3.1* may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.3.3 Coamings with height less than given in *Pt 4, Ch 7, 6.3 Hatch coamings 6.3.1* may normally be accepted for column-stabilised and tension-leg units after special consideration, *see also Pt 4, Ch 7, 6.3 Hatch coamings 6.3.4*.

6.3.4 Coaming heights on all units are also to satisfy the requirements for intact and damage stability, *see Pt 4, Ch 7, 4.5 External openings related to damage stability* and *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability*.

6.3.5 The thickness of the coamings is to be not less than the minimum thickness of the structures to which they are attached, or 11 mm, whichever is the lesser. Stiffening of the coaming is to be appropriate to its length and height. Scantlings of coamings more than 900 mm in height will be specially considered.

6.4 Manholes and flush scuttles

6.4.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.5 Companionways, doors and access arrangements on weather decks

6.5.1 The requirements of *Pt 3, Ch 11, 6.4 Companionways, doors and accesses on weather decks* of the Rules for Ships are to be complied with, as applicable.

6.5.2 For access to spaces in the oil storage area on units with tanks for the storage of oil in bulk, *see Pt 3, Ch 3, 2.11 Access arrangements and closing appliances*.

6.5.3 The height of doorway sills above deck sheathing, if fitted, is to be not less than 600 mm in Position 1, and not less than 380 mm in Position 2. For semi-submersible units, *see Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.3*.

6.5.4 Doorway sill heights on all units are also to satisfy the requirements for intact and damage stability, *see Pt 4, Ch 7, 4.5 External openings related to damage stability* and *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability*.

6.5.5 On ship units and other surface type oil storage units, direct access from the freeboard deck to the machinery space through exposed casings is not permitted, except when *Pt 4, Ch 7, 6.5 Companionways, doors and access arrangements on weather decks 6.5.6* applies. A door complying with *Pt 4, Ch 7, 6.5 Companionways, doors and access arrangements on weather decks 6.5.3* may, however, be fitted in an exposed machinery casing on these units, provided that it leads to a space or passageway which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door complying with *Pt 4, Ch 7, 6.5 Companionways, doors and access arrangements on weather decks 6.5.3*. The outer and

inner weathertight doors are to have sill heights of not less than 600 mm and 230 mm respectively and the space between is to be adequately drained by means of a screw plug or equivalent.

6.5.6 For ship units and other surface type oil storage units with freeboards greater than, or equal to, a Type B ship (as defined in the Load Line Convention), inner doors are not required for direct access to the engine room.

6.6 Side scuttles, windows and skylights

6.6.1 For ship units and other surface type units and self-elevating units, when afloat, the requirements of *Pt 3, Ch 11, 6.5 Side scuttles, windows and skylights* of the Rules for Ships are to be complied with, as applicable.

6.6.2 A plan showing the location of side scuttles and windows is to be submitted. Attention is to be given to any relevant Statutory Requirements of the Coastal State Authority where the unit is to operate and/or the National Authority of the country in which the unit is to be registered.

6.6.3 The location of windows and side scuttles and the provision of deadlights or storm covers on semi-submersible units will be specially considered in each case, see also *Pt 4, Ch 7, 4.5 External openings related to damage stability 4.5.1* and *Pt 4, Ch 7, 5.2 Column-stabilised units and tension-leg units 5.2.5*.

6.6.4 Windows and side scuttles are to be of the non-opening type where damage stability calculations indicate that they would become immersed as a result of specified damage.

■ *Section 7*
Tank access arrangements and closing appliances in oil storage units

7.1 General

7.1.1 The requirements of *Pt 3, Ch 11, 7 Tanker access arrangements and closing appliances* of the Rules for Ships are to be complied with, as applicable.

7.1.2 The height of coamings may be required to be increased if this is shown to be necessary by damage stability regulations.

7.1.3 The general requirements for access to spaces within the oil storage area are to comply with *Pt 3, Ch 3, 2.11 Access arrangements and closing appliances*.

7.1.4 Small openings are to be kept clear of other access openings.

7.1.5 Access openings are to have smooth edges and edge stiffening is also to be arranged in regions of high stress.

■ *Section 8*
Ventilators

8.1 General

8.1.1 The requirements of *Pt 3, Ch 12, 2 Ventilators* of the Rules for Ships are to be complied with, as applicable.

8.1.2 Ventilators from deep tanks and tunnels passing through pontoons, columns and 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

8.1.3 Ventilator coaming heights and closing appliances on all units are also to satisfy the requirements for intact and damage stability, *see Pt 4, Ch 7, 4.5 External openings related to damage stability* and *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability*.

8.1.4 On self-elevating units, it is recommended that closing appliances for ventilators situated on the freeboard deck are fitted at or below the deck level.

8.1.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw-down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm on self-elevating units. On self-elevating units, a notice indicating 'keep closed while unit is afloat' is to be attached to the head.

8.1.6 A ventilator head not forming part of the closing arrangements is to be not less than 5,0 mm thick on column-stabilised units and 6,5 mm thick on other units.

8.1.7 Wall ventilators (jalousies) may be accepted, provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles, or equivalent arrangements provided.

8.1.8 Fire dampers are not acceptable as ventilator closing appliances unless they are of substantial construction, gasketed, and able to be secured weathertight in the closed position.

8.1.9 Reference should be made to *Pt 4, Ch 7, 8.1 General 8.1.3* concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with *Pt 3, Ch 12, 2.3 Closing appliances 2.3.1* of the Rules for Ships.

■ *Section 9*
Air and sounding pipes

9.1 General

9.1.1 The requirements of *Pt 3, Ch 12, 3 Air and sounding pipes* of the Rules for Ships and *Pt 5, Ch 13, 12 Air, overflow and sounding pipes* of the Rules for Ships are to be complied with, as applicable.

9.1.2 Air pipes are generally to be led to an exposed deck and are to be well protected from mechanical damage.

9.1.3 Air pipes are also to satisfy the requirements for intact and damage stability, *see Pt 4, Ch 7, 4.5 External openings related to damage stability* and *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability*.

9.1.4 All openings of air and sounding pipes are to be provided with approved automatic type closing appliances which prevent the free entry of water and excessive pressure imposed on the tank.

9.1.5 Pressure/vacuum valves as required by *Pt 5, Ch 15, 1 General* may be accepted as closing appliances for oil storage tanks.

■ *Section 10*
Scuppers and sanitary discharges

10.1 General

10.1.1 The requirements of *Pt 3, Ch 12, 4 Scuppers and sanitary discharges* of the Rules for Ships are to be complied with, as applicable.

10.1.2 The additional requirements contained within this Section are applicable to semi-submersible and self-elevating units only.

10.1.3 Normally, each separate overboard discharge from an enclosed space is to be fitted with an automatic non-return valve at the shell boundary. Where the inboard end of a discharge is situated below the worst damage water line, the non-return valve is to be of a type which is effective at the worst expected inclination after damage, whatever the orientation, and is to have a positive means of closing, operable from a readily accessible position above the damage water line. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.4 The requirements for non-return valves are applicable only to those discharges which remain open while the unit is afloat during normal operation. For discharges which are closed while the unit is afloat, such as gravity drains from tanks, a single screw-down valve operated from the freeboard deck is considered to provide sufficient protection. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.5 The non-return valve required by *Pt 4, Ch 7, 10.1 General 10.1.3* is to be mounted directly on the shell and secured in accordance with *Pt 5, Ch 13, 2.4 Attachment of valves to watertight plating* of the Rules for Ships . If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

10.1.6 Discharge piping, situated between the sea level and the bottom of the upper hull of semi-submersible units and below the bottom shell of the self-elevating units when in the elevated position, is to be of substantial construction, well secured and protected.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all unit types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Welding connection details, defined practices and sequence, consumables and equipment, procedures, workmanship and inspection.
(b) End connection scantlings and constructional details for longitudinals, beams, frames and bulkhead stiffeners.
(c) Primary member proportions, stiffening and construction details.

1.1.3 All units are to comply with the requirements of *Pt 3, Ch 10 Welding and Structural Details* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), as applicable to the type of unit. Additional requirements as indicated in the following Sections should also be complied with, as applicable.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

■ *Section 2* Welding

2.1 General

2.1.1 Requirements for welding are given in *Ch 12 Welding Qualifications* and *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and general requirements for hull construction are also given in *Pt 3, Ch 10, 2 Welding* of the Rules for Ships.

2.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

2.2 Impact test requirements

2.2.1 Charpy V-notch impact tests are to be carried out in the weld metal, fusion line and heat affected zone in accordance with *Pt 4, Ch 8, 2.2 Impact test requirements 2.2.2* to *Pt 4, Ch 8, 2.2 Impact test requirements 2.2.4*.

2.2.2 For special structure, the impact test temperature and minimum absorbed energy for the weld and heat affected zone are to be the same as that specified for the base materials being welded.

2.2.3 For primary and secondary structure, the impact test temperature and the minimum absorbed energy for the weld metal and heat affected zone are to be in accordance with the requirements of the material grade being welded, as specified in *Ch 12, 2.12 Mechanical test acceptance criteria for steels 2.12.4* in *Ch 12 Welding Qualifications* of the Rules for Materials.

2.2.4 Fabrications whose thickness exceeds 65 mm are, in general, to be subjected to a post weld heat treatment. Impact tests are required to be made on specimens heat treated in the same manner as the actual construction. The absorbed energy is to be in accordance with *Pt 4, Ch 8, 2.2 Impact test requirements 2.2.2* and *Pt 4, Ch 8, 2.2 Impact test requirements 2.2.3*; however, the test temperatures may be 10°C higher.

2.3 Workmanship and inspection

2.3.1 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Builder. The locations and numbers of checkpoints are to be agreed between the Builder and the Surveyor. Special attention is to be paid to the welded connections of primary bracings and their end connections and other structure defined as special in *Pt 4, Ch 2, 2 Structural categories*.

2.3.2 Additional locations for NDE for ship units and other surface type units are shown in *Pt 4, Ch 8, 2.3 Workmanship and inspection 2.3.6*.

2.3.3 Typical locations for NDE and the recommended number of checkpoints to be taken in column-stabilised and self-elevating units are shown in *Pt 4, Ch 8, 2.3 Workmanship and inspection 2.3.6*. For other unit types, the extent of NDE will be specially considered in each case. Critical locations as identified by LR's *ShipRight Fatigue Design Assessment* and other relevant fatigue calculations are also to be considered, where applicable. A document detailing the proposed items to be examined is to be submitted by the Builder for approval.

2.3.4 For the hull structure of units designed to operate in low air/sea temperatures, the recommended extent of non-destructive examination will be specially considered.

2.3.5 All NDE is to be performed in accordance with the requirements specified in *Ch 13, 2 Specific requirements for ship hull structure and machinery* of the Rules for Materials.

2.3.6 In general, fabrication tolerances are to comply with *Pt 4, Ch 8, 6 Fabrication tolerances*. It is important to ensure that compatibility exists between design calculations and construction standards, particularly in fatigue sensitive areas.

Table 8.2.1 Additional non-destructive examination of welds on surface type units (as applicable)

Recommended extent of testing, *see* Note 1 General, *see* Notes 8 and 9		
Structural item	Local	Checkpoints, *see* Note 1
Penetrations and attachments to hull, e.g. sea inlets, piping, anode supports	Throughout	100%
Moonpool integration structure	Throughout	*See* Notes 2 and 4
Topside support structure connections to hull and hull structure in way	Throughout	25%, *see* Notes 4 and 5
Flare stack and crane pedestal structure	Throughout	50%, *see* Notes 4 and 5
Connections to deck	Local	100%
Other structural items	Throughout	*See* Notes 3 and 4
Side shell butts, seams and intersection welds where vessel is strengthened for operations in ice	Forward end	*See* Note 6
	Remainder	*See* Note 7
Exposed shell butts, seams and intersection welds where vessel is designed for low temperature operations	Throughout	*See* Note 7
Local areas identified as fatigue sensitive, e.g.: • Identified bracket connections at intersections of side shell longitudinals and transverse frames and bulkheads	Local	*See* Note 3

• Key locations identified on moonpool integration structure	Local	100%
• Topside support stool welds to upper deck and underdeck welds in way	Local	100%
• Flare stack support welds to upper deck and underdeck welds in way	Local	100%
Other items	Local	*See* Notes 3 and 4

NOTES

1. The diameter of each checkpoint is to be between 0,3 and 0,5 m, and volumetric and magnetic particle checks are to be carried out unless indicated otherwise.

2. 10% selection of butts and seams and 20% at intersections. Particular attention is to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.

3. Random selection to the Surveyor's satisfaction.

4. Particular attention is also given to ends of bracket connections where fitted.

5. Particular attention to be given in way of weld intersections and discontinuities at stop and start positions.

6. 10% of butts and seams and 30% at intersections. Particular attention to be taken in way of stops and starts of automatic and semiautomatic welding during fabrication.

7. 10% selection of butts and seams and 25% at intersections. Particular attention to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.

8. Agreed locations are not to be indicated on blocks prior to the welding taking place, nor is any special treatment to be given at these locations.

9. Particular attention is to be given to repair rates. Additional welds are to be tested in the event that defects such as lack of fusion or incomplete penetration are repeatedly observed.

Table 8.2.2 Non-destructive examination of welds on column-stabilised and self-elevating units

Recommended extent of testing, *see* Note 9 General, *see* Note 1		
Structural item	Volumetric checkpoints	Magnetic particle checkpoints
Bracing butt and seam welds	100%	100%
Bracing weld connections to: • columns • pontoons • upper hull • lower nodes	100%	100%
Attachments to legs and bracings	—	100%
Penetrations through legs and bracings	100%	100%
Bracing shell attachment of diaphragms, gussets, stiffeners	100%	100%
Column shell butts and seams	*See* Note 4	20%
Column weld connections to: • pontoons • upper hull • in way of anchor fairleads and sheaves	100%	100%

Internal column structure connections	5%, *see* Note 5	*See* Note 3
Pontoons, hull, shell and bulkhead butts/seams	*See* Note 4	20%
Leg footings or mats	*See* Note 4	20%
Internal pontoon structure	5%, *see* Note 5	*See* Note 3
Hull penetrations, sub-sea inlets, anode and attachments, piping connection supports, etc.	100%	–
Bilge keel butts	100%	100%
Self-elevating unit leg connections • leg chords • leg trusses • leg attachments to footings or mats • butts and seams in chords and trusses	100%	100%
Upper hull: Main bulkheads/deck girders	*See* Notes 2 & 4	*See* Note 6
Strength decks and drill floor	*See* Notes 2 & 4	*See* Note 7
In way of windlasses and mooring winches	–	100%
Topside support structure connections to deck	25%	25%
Flare stack, crane pedestals and gusset connections to deck	100%	100%
Drill floor, derrick substructure and moonpool structure	*See* Notes 4 and 7	*See* Note 7
Helideck primary support, cantilevered life boat platform primary support	20%	20%
Helideck and lifeboat platform remainder	*See* Note 8	–
Other items	*See* Note 8	*See* Note 8

NOTES

1. Back-up structure of the items in question is also to be included, where applicable.
2. 100% in way of full penetration welding at end of diaphragm plates, gussets, stiffeners, etc.
3. 50% in way of fillet welds around stiffener ends, notches, cut-outs, drain hole openings, etc.
4. 10% selection of butts and seams and 20% at intersections. Particular attention to be taken in way of stops and starts of automatic and semi-automatic welding during fabrication.
5. 10% random selection of butt welds, of pontoon and column shell longitudinal stiffeners and transverse and longitudinal bulkheads stiffeners.
6. 10% random selection of fillet welds in way of stiffener ends, drain hole openings, cut-outs, notches, etc.
7. Girder and sub-structure butt welds 100% UT; principal connections to deck and main structure 100% UT and 100% MPI.
8. Random spot checks to the Surveyor's satisfaction.
9. The diameter of each checkpoint is to be between 0,3 and 0,5 m.

2.4 Fillet welds

2.4.1 Additional weld factors for structure not specifically covered by the Rules for Ships are given in *Pt 4, Ch 8, 2.4 Fillet welds 2.4.1*.

Table 8.2.3 Additional weld factors

Item	Weld factor	Remarks
(1) General application:		

(a) Shell boundaries of columns to lower and upper hulls	full penetration	except as required below
(b) Internal watertight or oiltight plate boundaries	0,34	generally, but alternative proposals will be considered in specific areas
(2) (a) Upper hull framing and hull framing on self-elevating units:		
(i) Webs of web frames and stringers:		
• to shell	0,16	
• to face plate	0,13	
(ii) Tank side brackets to shell and inner bottom	0,34	
(b) Primary hull framing and girders on lower hulls, columns and caissons of column-stabilised units		to be in accordance with the Rules for Ships
(3) Decks and supporting structure:		
Primary deck girders and connections between primary members on column-stabilised units.		generally to comply with the Rules for Ships, but full penetration welding may be required
(4) Self-elevating units:		
(a) Leg construction, general	full penetration	
(b) Leg connections to footings or mats	full penetration	
(c) Internal webs, girders and bulkheads in footings and mats	0,44	full penetration may be required
(d) Internal stiffeners in footings and mats	0,34	
(e) Jackhouses, general	0,44	full penetration may be required
(f) Bulkheads and primary structures in way of leg wells	0,44	full penetration may be required
(5) Main bracings and ‘K’ joints, etc.:		
(a) Ring frames, girders and stiffeners	full penetration	generally, but alternative proposals may be considered
(b) Shell boundaries and end connections including brackets, gussets and cruciform plates	full penetration	
(6) Miscellaneous structures, fittings and equipment:		
(a) Rings and coamings for manhole type covers to shell on stability columns and lower hulls	full penetration	generally, but alternative proposals may be considered
(b) Rings for manhole type covers, to deck or bulk head	0,34	
(c) Frames of watertight and weathertight bulk head doors	0,34	
(d) Stiffening of doors	0,21	
(e) Ventilator, air pipes, etc. coamings to deck	0,34	Load line positions 1 and 2
(f) Ventilator, etc. fittings	0,21	elsewhere
(g) Scuppers and discharges, to deck	0,44	
(h) Masts, flare structures, derrick posts, crane pedestals, etc. to deck	0,44	full penetration welding may be required
(j) Deck machinery seats to deck	0,21	generally
(k) Mooring equipment seats and fairleads	0,44	full penetration welding may be required
(l) Bulwark stays to deck	0,21	
(m) Bulwark attachment to deck	0,34	

(n) Guard rails, stanchions, etc. to deck	0,34	
(o) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(p) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld,minimum throat thickness 3 mm
(q) Fabricated anchors	full penetration	
(r) Turret and swivel supports	0,44	full penetration welding may be required
(s) Process plant stools to deck	0,44	full penetration welding may be required
(t) supports for risers, umbilicals and caissons	0,44	full penetration welding may be required

2.4.2 Continuous welding is to be adopted in the following locations:

(a) All weldings inside tanks and peak compartments.
(b) Primary and secondary members to shell in lower hulls and stability columns.
(c) Primary and secondary members to main bracings, trusses or 'K' joints.

2.5 Welding of tubular members

2.5.1 Welding is to comply with agreed Internationally or Nationally accepted Codes such as AWS or API and all welding generally is to conform to the following:

(a) All steel is to be joined by complete penetration groove welds.
(b) Unless single sided welding has been agreed for the particular weld configuration, double sided welds are to be used, wherever practicable.
(c) In lattice type structures, a minimum weld attachment length at the cord of 1,5 times the brace wall thickness is required at all locations. This is based on fatigue considerations.
(d) Care is to be taken to ensure the weld surface profile is smooth and blends with the parent material.
(e) Backing strips are not to be used unless specially agreed with LR.
(f) Root gaps are to be generally in the range of 3 to 6 mm.
(g) Bevels are to be such that the included angle is in the range 45° to 60°. However, when the dihedral angle is less than 45°, the included angle may be reduced as indicated for locations 4 and 5, *see Pt 4, Ch 8, 2.5 Welding of tubular members 2.5.2*.
(h) Where saddle weld toe grinding has been agreed as a method of improving fatigue life, at the locations agreed, the grinding of the weld toe is to produce a smooth transition between the weld and the parent plate. The grinding should remove all defects, slag inclusions and any undercut. Overgrinding into the parent plate is not to exceed 2 mm or 0,05 times the plate thickness, whichever is less. The grinding tool should preferably have a spherical head (e.g. a tungsten carbide burr) and, in general, disc-grinders are to be avoided except for initial heavy grinding. Any marks made by rotation of the grinding tool are to be aligned with the direction of stress. The surface of the main body of the weld may be dressed to produce a better concave profile if the as-welded profile is poor, *see Pt 4, Ch 8, 2.5 Welding of tubular members 2.5.2* and *Pt 4, Ch 8, 2.5 Welding of tubular members 2.5.2*. Care must be exercised in order that overgrinding does not excessively reduce the size of the attachment weld and in no case less than that required by the Rules.

2.5.2 Locations 1, 2, 3, 4 and 5 are related to the local dihedral angle (the angle between the brace wall and chord wall). Transition from one detail to another is to be by gradual uniform level preparation and surface profile, *see Pt 4, Ch 8, 2.5 Welding of tubular members 2.5.2*.

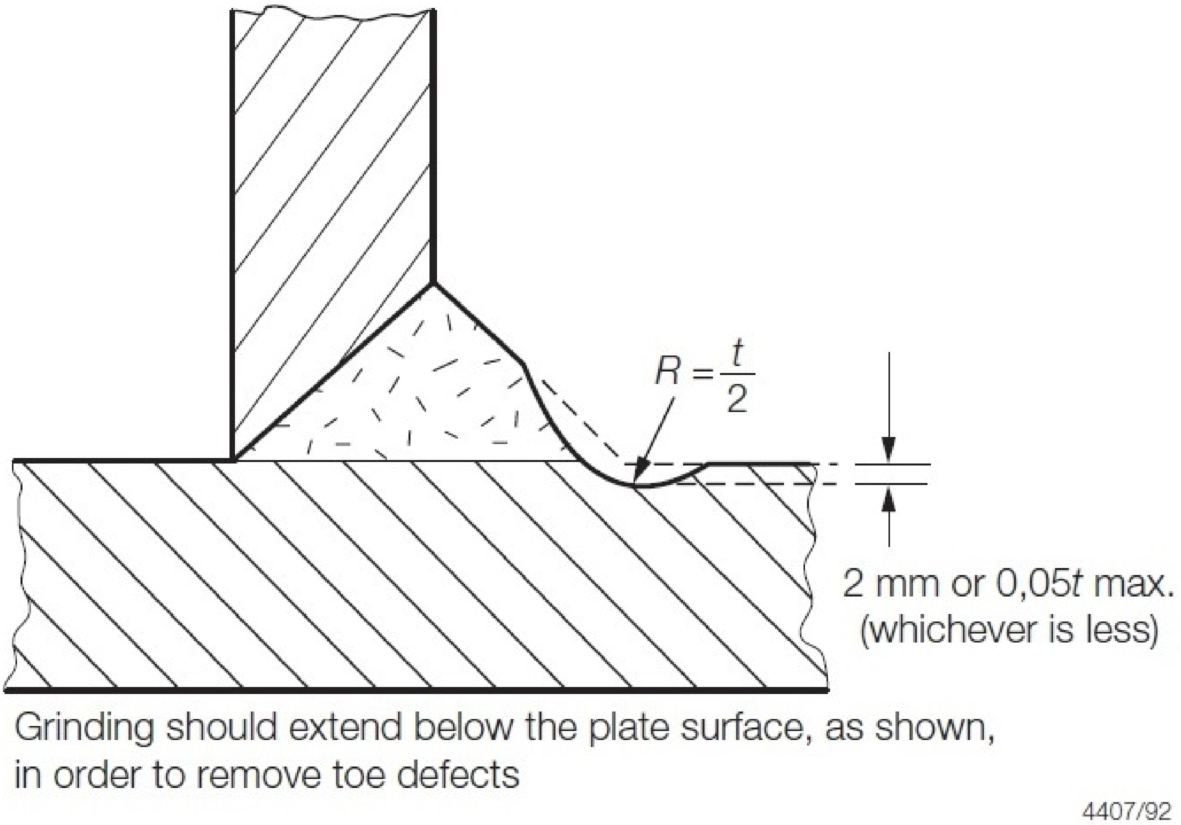
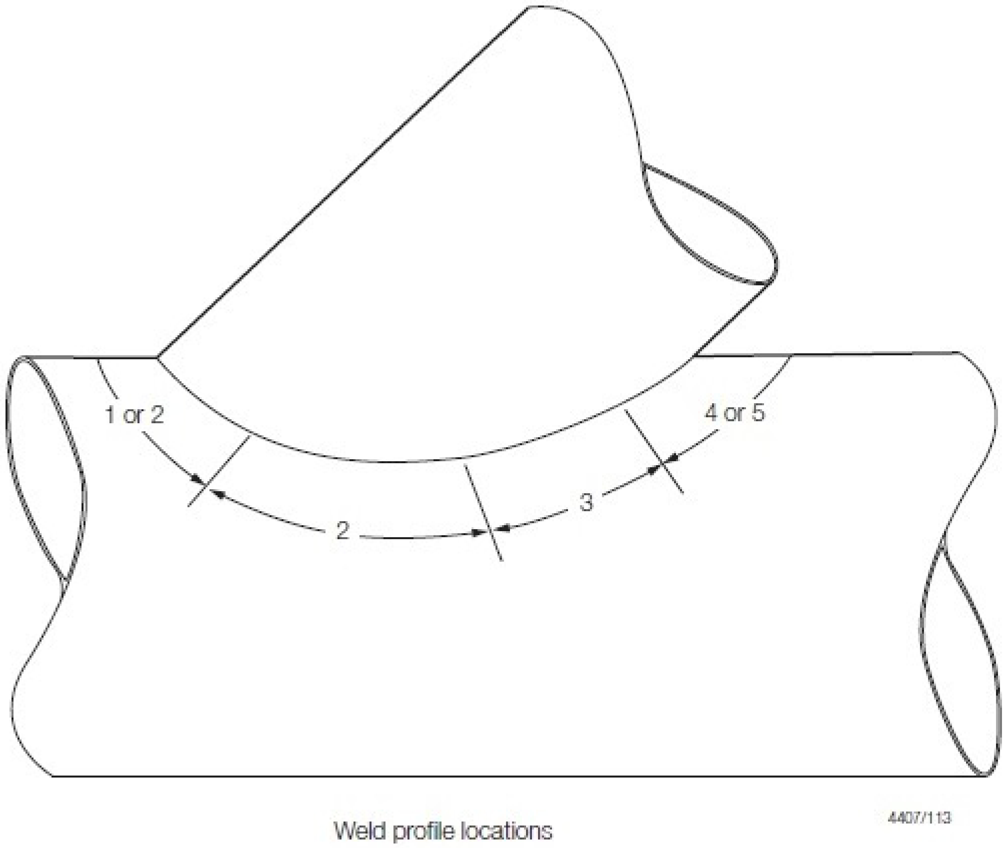


Figure 8.2.1 Grinding of weld toe

Location	Applicable range of local dihedral angle ψ	
1	180° — 135°	*See Note 1*
2	150° — 90°	*See Note 2*
3	90° — 50°	*See Note 3*
4	75° — 30°	*See Note 4*
5	40° — 15°	*See Note 5*



Weld profile locations

Figure 8.2.2 Local dihedral angle for weld profile locations

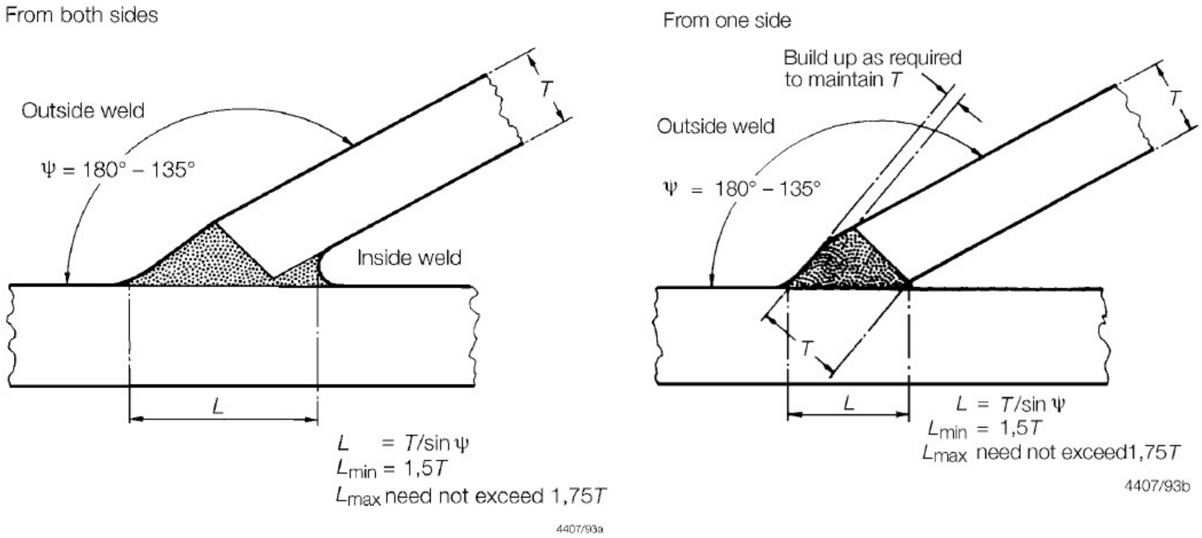


Figure 8.2.3 Welding at location 1

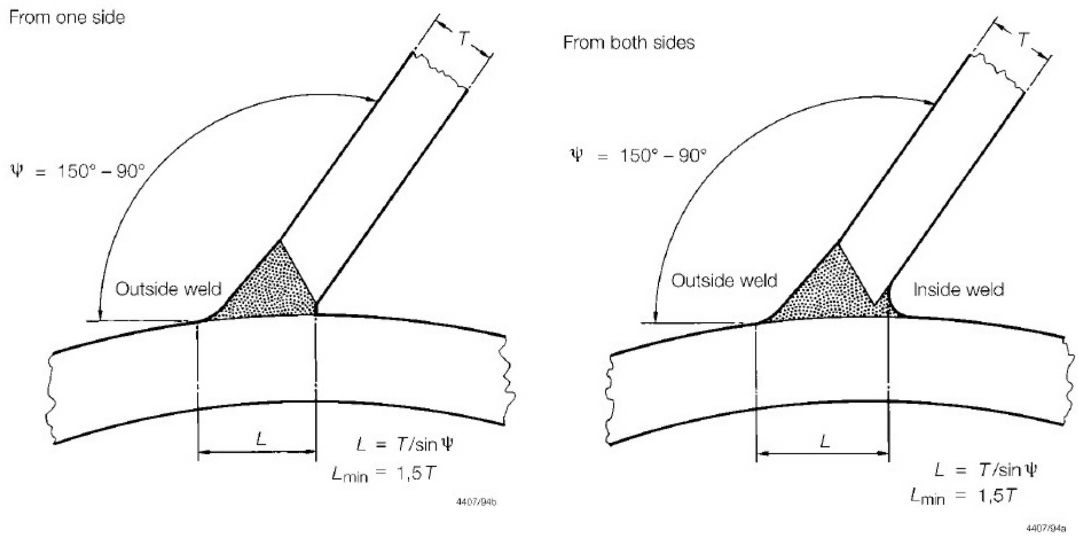


Figure 8.2.4 Welding at location 2

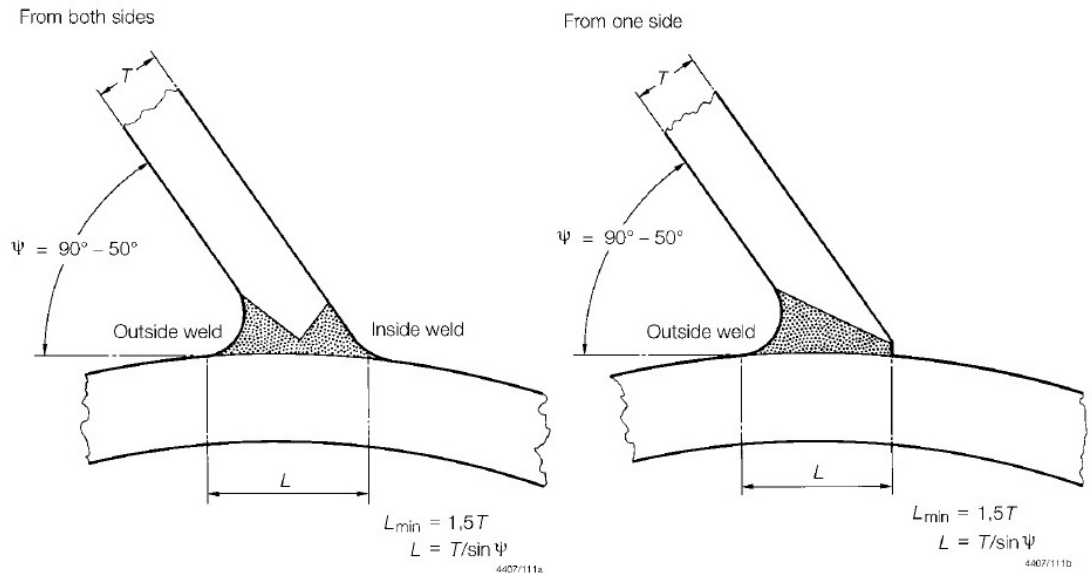


Figure 8.2.5 Welding at location 3

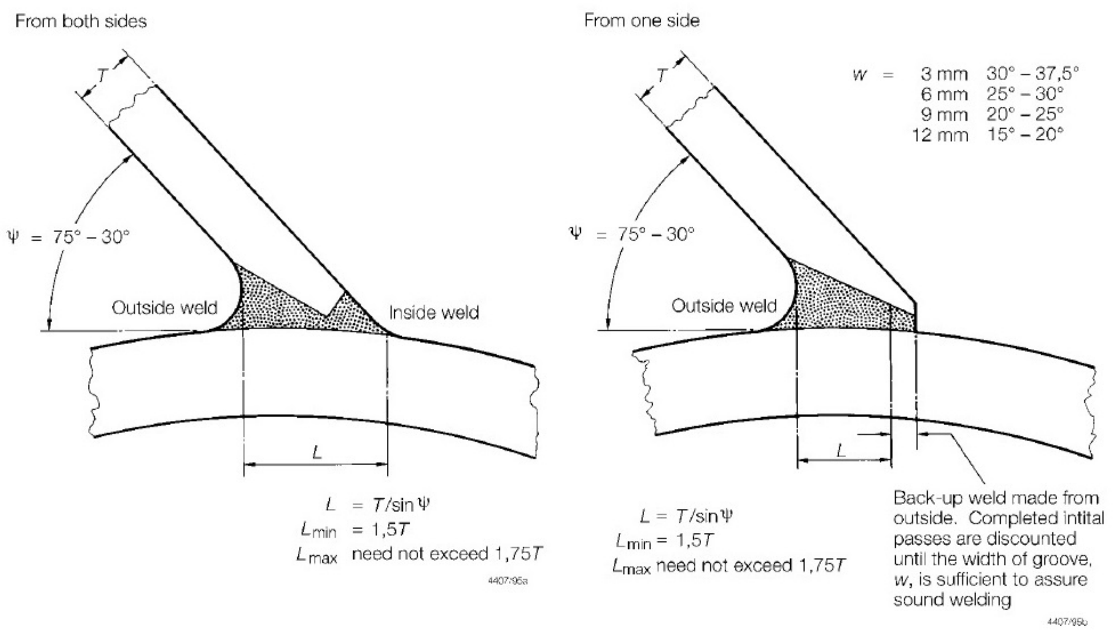


Figure 8.2.6 Welding at location 4

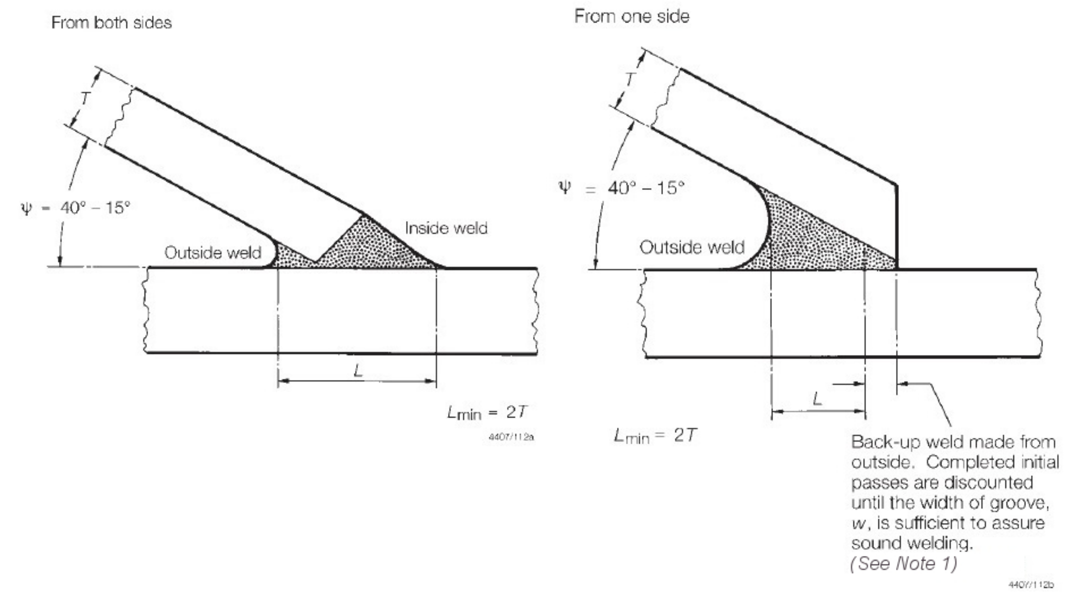


Figure 8.2.7 Welding at location 5

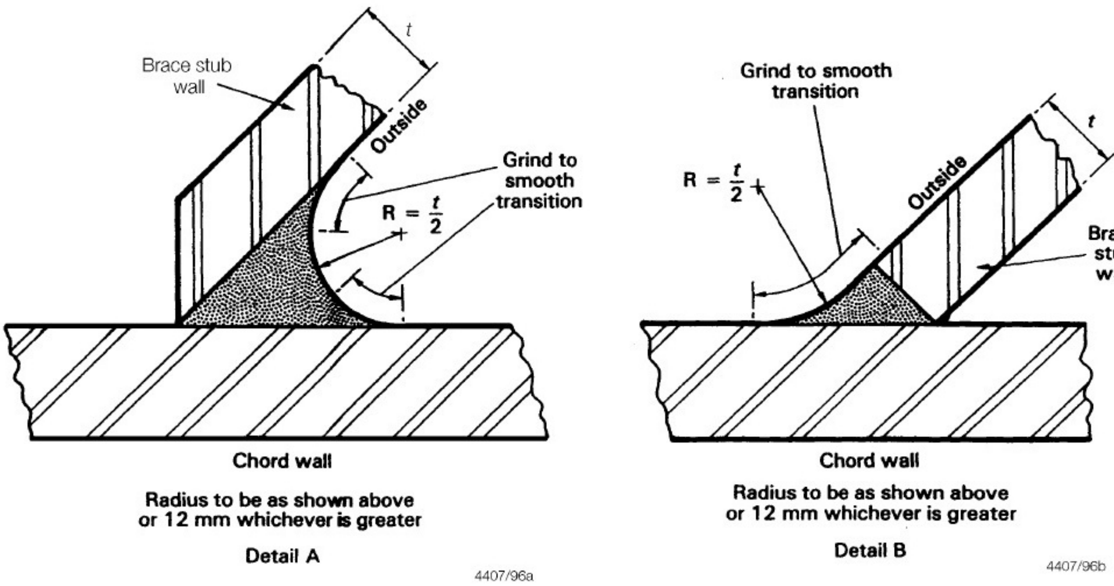


Figure 8.2.8 Weld grinding

Section 3
Secondary member end connections

3.1 General

3.1.1 For ship units, the design of secondary member end connections is to comply with *Pt 10 SHIP UNITS*. For other unit types, the design of secondary member end connections is to comply with *Pt 3, Ch 10, 3 Secondary member end connections* of the Rules for Ships.

Section 4
Construction details for primary members

4.1 General

4.1.1 For ship units, the design of construction details for primary members is to comply with *Pt 10 SHIP UNITS*. For other unit types, the design of construction details for primary members is to comply with *Pt 3, Ch 10, 4 Construction details for primary members* of the Rules for Ships.

4.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

4.2 Geometric properties and proportions

4.2.1 The minimum web thickness of primary shell members in the lower hulls of column-stabilised units is to be not less than 0,017 s_{w} , where s_{w} is spacing of stiffeners on member web, or depth of unstiffened web, in mm.

Section 5
Structural details

5.1 General

5.1.1 For ship units, the design of structural details is to comply with *Pt 10 SHIP UNITS*. For other unit types, the design of structural details is to comply with *Pt 3, Ch 10, 5 Structural details* of the Rules for Ships.

5.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

5.2 Arrangements at intersections of continuous secondary and primary members

5.2.1 In the lower hulls of column-stabilised units, where primary member webs are slotted for the passage of secondary members, web stiffeners are generally to be fitted normal to the face plate of the member to provide adequate support for the loads transmitted. The ends of web stiffeners are to be attached to the secondary members.

5.2.2 Web stiffeners may be flat bars of thickness, t_{w} , with a minimum depth of 0,08 d_{w} or 75 mm, whichever is the greater. Alternative sections of equivalent moment of inertia may be adopted. The direct stress in the web stiffeners is to be determined in accordance with the Rules for Ships.

5.2.3 For units other than ship units and other surface type units, direct stress in the vertical web stiffener and the shear stresses in the lug, collar plate and weld connections are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (a) in *Pt 4, Ch 5, 2 Permissible stresses*

5.2.4 For units other than ship units and other surface type units, the head h_1 used to calculate load transmitted to connections of secondary members is to be obtained from the following, as applicable:

(a) h_0 from *Pt 4, Ch 6, 3.3 Self-elevating units 3.3.4* in *Pt 4, Ch 6 Local Strength*.

(b) h_T from *Pt 4, Ch 6, 3.4 Buoys and deep draught caissons 3.4.7* in *Pt 4, Ch 6 Local Strength*.

(c) h_4 from *Pt 4, Ch 6, 7.3 Watertight and deep tank bulkheads 7.3.4* in *Pt 4, Ch 6 Local Strength*.

5.3 Openings

5.3.1 Penetrations in main bracing members are to be avoided as far as possible. Details of essential penetrations or openings in main bracing members are to be submitted for consideration.

5.4 Other fittings and attachments

5.4.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and the material grade and quality of the bar are to be to the same standard as the deck plate to which it is attached.

5.4.2 Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking into account the intended structural arrangement and attachment details. In general, the material grade and the quality of the attachment are to be to the same standard as the gunwale plates.

5.4.3 Fittings and attachments to main bracing members are to be avoided as far as possible. Where they are necessary, full details are to be submitted for consideration.

■ *Section 6* Fabrication tolerances

6.1 General

6.1.1 All fabrication tolerances are to be in accordance with good shipbuilding practice and be agreed with LR before fabrication is commenced. Where appropriate, tolerances are to comply with a National Standard. In general, the tolerances for the fabrication of structural members for fatigue sensitive areas are to comply with the requirements of this Section.

6.1.2 For cylindrical members, the out of roundness is not to exceed 0,5 per cent of the true mean radius or 25 mm of the true mean internal diameter, whichever is the lesser. Applicability of absolute out of roundness tolerances to structures with large diameter to wall thickness ratios (D/t>300) will be specially considered e.g. circumturret bulkhead.

6.1.3 When measuring cylindrical members, the out of roundness is to be measured always as a deviation from the true mean radius in order to avoid errors.

6.1.4 Cylindrical members are not to deviate from straightness by 3 mm or *l* mm, whichever is the greater, where *l* is the length of the member, in metres.

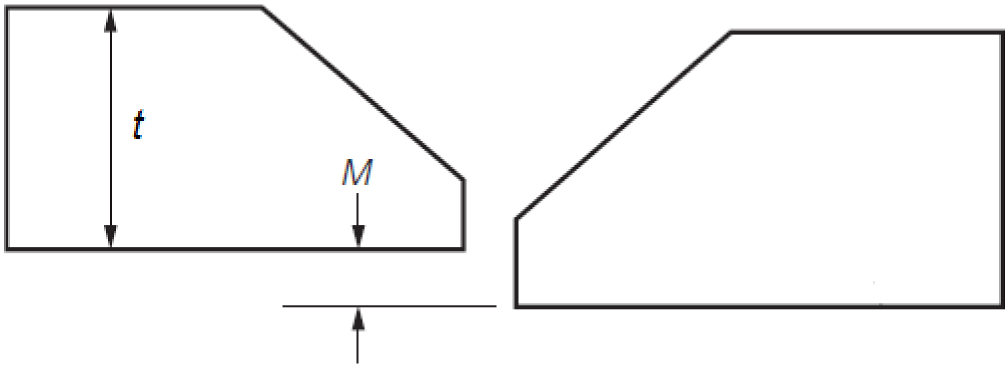
6.1.5 The misalignment of plate edges in butt welds is not to exceed the lesser of the following values:

- Special structure 0,1*t* or 3 mm
- Primary structure 0,15*t* or 3 mm
- Secondary structure 0,2*t* or 4 mm

where

t = thickness of the thinnest plate, in mm.

See Pt 4, Ch 8, 6.1 General 6.1.5.



t = thickness of the thinner member
M = misalignment

Figure 8.6.1 Misalignment of plate edges in butt welds

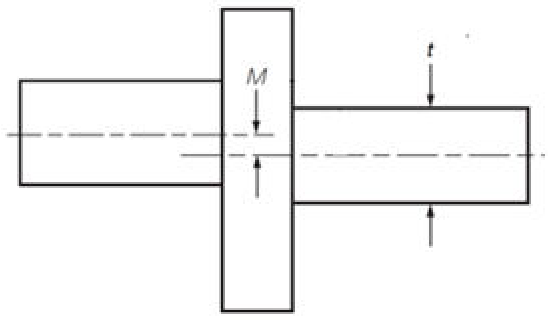
6.1.6 Misalignment of non-continuous plates such as cruciform joints is not to exceed the lesser of the following values:

- Special structure 0,2*t* or 4 mm
- Primary structure 0,3*t* or 4 mm
- Secondary structure 0,5*t* or 5 mm

where

t = thickness of the thinnest plate, in mm.

See Pt 4, Ch 8, 6.1 General 6.1.6.



t = thickness of the thinner member
M = misalignment

Figure 8.6.2 Misalignment of non-continuous plates

6.1.7 Plate deformation measured at the mid point between stiffeners or support points is not to exceed the lesser of the following values:

- Special structure $\frac{s}{200}$ mm
- Primary structure $\frac{s}{130}$ or t mm
- Secondary structure $\frac{s}{80}$ or t mm

where

s = stiffener spacing or unsupported panel width, in mm

t = plate thickness, in mm.

See Pt 4, Ch 8, 6.1 General 6.1.7.

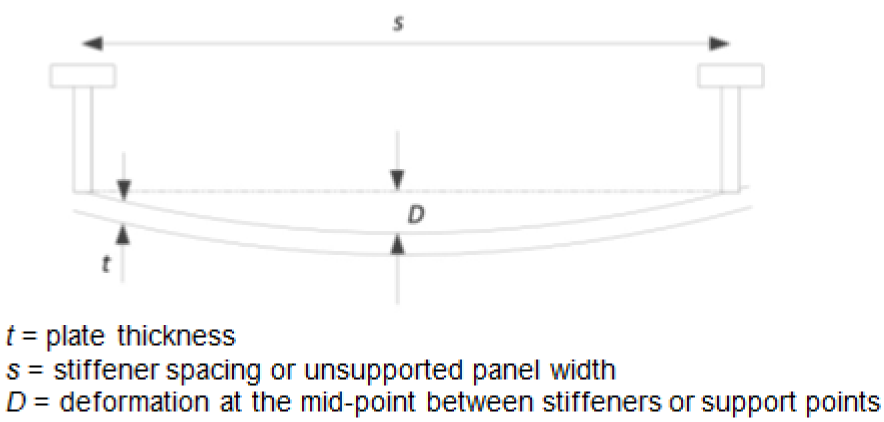


Figure 8.6.3 Plate deformation

Section

Section 1 Anchoring equipment

1.1 General

1.1.1 For self-propelled units to be assigned the figure **(1)** in the character of Classification, the anchoring equipment, i.e. anchors, cables, windlass and winches, etc. necessary for the unit during ocean voyages or location moves, is to be as required by this Section. The Regulations governing the assignment of the figure **(1)** for equipment are given in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*.

1.1.2 When the equipment fitted to the unit is designed primarily as positional mooring equipment, consideration will be given to accepting the proposed equipment as equivalent to the Rule requirements but only if the arrangements are such that it can be efficiently used as anchoring equipment. *See also Pt 1, Ch 2, 2.3 Character Symbols 2.3.3* and *Pt 3, Ch 10 Positional Mooring Systems*.

1.1.3 Where the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the unit, the character letter **N** will be assigned, *see also Pt 1, Ch 2, 2.2 Modes of operation 2.2.2*.

1.2 Equipment number

1.2.1 The requirement for anchors, cables, wires and ropes is to be based on an Equipment Number calculated as follows:

Equipment Number = $\Delta^{2/3} + 2,0A_1 + \frac{A_2}{10}$

where

Δ = moulded displacement in transit condition, in tonnes

A_1 = projected area perpendicular to wind direction when at anchor, in m^2

A_2 = projected area parallel to wind direction when at anchor, in m^2

In calculating the areas A_1 and A_2 :

- Masking effect can be taken into account for columns;
- Open trusswork of derricks, booms and towers, etc. may be approximated by taking 30 per cent of the block area of each side, i.e. 60 per cent of the projected area of one side for double sided trusswork.
- When calculating projected areas, account is to be taken of topside process facilities. Special consideration will be given to structure extending outside of the Rule length, *L*.

1.3 Determination of equipment

1.3.1 The basic equipment of anchors and cables is to be determined from *Pt 4, Ch 9, 1.4 Anchors 1.4.6* and associated notes. *Pt 4, Ch 9, 1.4 Anchors 1.4.6* is based on the following assumptions:

(a) The anchors will be high holding power anchors of an approved design, *see Pt 4, Ch 9, 1.5 High holding power anchors*.

(b) The chain cable will be in accordance with the requirements of *Pt 4, Ch 9, 1.6 Chain cables*.

1.3.2 Where the equipment is based on *Pt 4, Ch 9, 1.1 General 1.1.2*, the sizes of individual anchors are not to exceed the values given in *Pt 4, Ch 9, 1.4 Anchors 1.4.6* by more than seven per cent unless the cable sizes are increased as appropriate.

1.3.3 Where the equipment is based on *Pt 4, Ch 9, 1.1 General 1.1.2*, the minimum cable strength is to be maintained and *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.6* is also to be complied with.

1.4 Anchors

1.4.1 Two anchors are to be fitted and arranged so that they may be readily dropped should an emergency occur.

1.4.2 The mass of each anchor is to be as given in*Pt 4, Ch 9, 1.4 Anchors 1.4.6*except that one anchor may weigh seven per cent less than the Table weight so long as the total weight of the two anchors attached to the cables is not less than twice the tabular weight for one anchor.

1.4.3 Anchors are to be of approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is a considerable change of section.

1.4.4 Positional mooring anchors of the type which are generally similar to conventional marine anchors but which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not normally be accepted as anchoring equipment in accordance with these Rules.

1.4.5 If ordinary ship type stockless bower anchors, not approved as high holding power anchors, are to be used as Rule equipment, the mass of each anchor is to be not less than 1,33 times that listed in *Pt 4, Ch 9, 1.4 Anchors 1.4.6* for the unit's Equipment Number.

1.4.6 The requirements for manufacture, proof testing and identification of anchors are to be in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Table 9.1.1 Equipment - Anchors and chain cables

Equipment number		Equipment Letter	High holding power anchor mass, in kg	Stud link chain cable			
Exceeding	Not exceeding			Length per anchor, in metres	Diameter, in mm		
					Grade U1	Grade U2	Grade U3
50	70	A	140	110	14	12,5	—
70	90	B	180	110	16	14	—
90	110	C	230	110	17,5	16	—
110	130	D	270	110	19	17,5	—
130	150	E	310	137,5	20,5	17,5	—
150	175	F	360	137,5	22	19	—
175	205	G	430	137,5	24	20,5	—
205	240	H	500	137,5	26	22	20,5
240	280	I	590	165	28	24	22
280	320	J	680	165	30	26	24
320	360	K	770	165	32	28	24
360	400	L	860	192,5	34	30	26
400	450	M	970	192,5	36	32	28
450	500	N	1080	192,5	38	34	30
500	550	O	1190	192,5	40	34	30
550	600	P	1300	220	42	36	32
600	660	Q	1440	220	44	38	34
660	720	R	1580	220	46	40	36

720	780	S	1710	220	48	42	36
780	840	T	1850	220	50	44	38
840	910	U	1990	220	52	46	40
910	980	V	2140	247,5	54	48	42
980	1060	W	2290	247,5	56	50	44
1060	1140	X	2470	247,5	58	50	46
1140	1220	Y	2660	247,5	60	52	46
1220	1300	Z	2840	247,5	62	54	48
1300	1390	A†	3040	247,5	64	56	50
1390	1480	B†	3240	275	66	58	50
1480	1570	C†	3440	275	68	60	52
1570	1670	D†	3670	275	70	62	54
1670	1790	E†	3940	275	73	64	56
1790	1930	F†	4210	275	76	66	58
1930	2080	G†	4500	275	78	68	60
2080	2230	H†	4840	302,5	81	70	62
2230	2380	I†	5180	302,5	84	73	64
2380	2530	J†	5510	302,5	87	76	66
2530	2700	K†	5850	302,5	90	78	68
2700	2870	L†	6230	302,5	92	81	70
2870	3040	M†	6530	302,5	95	84	73
3040	3210	N†	6980	330	97	84	76
3210	3400	O†	7430	330	100	87	78
3400	3600	P†	7880	330	102	90	78
3600	3800	Q†	8330	330	105	92	81
3800	4000	R†	8780	330	107	95	84
4000	4200	S†	9250	330	111	97	87
4200	4400	T†	9700	357,5	114	100	87
4400	4600	U†	10100	357,5	117	102	90
4600	4800	V†	10600	357,5	120	105	92
4800	5000	W†	11000	371,5	122	107	95
5000	5200	X†	11600	371,5	124	111	97
5200	5500	Y†	12100	371,5	127	111	97
5500	5800	Z†	12700	371,5	130	114	100
5800	6100	A*	13400	371,5	132	117	102
6100	6500	B*	14100	371,5	—	120	107
6500	6900	C*	15000	385	—	124	111
6900	7400	D*	16000	385	—	127	114

7400	7900	E*	17500	385	—	132	117
7900	8400	F	18500	385	—	137	122
8400	8900	G*	19500	385	—	142	1127
8900	9400	H*	20500	385	—	147	132
9400	10000	I*	22000	385	—	152	132
10000	10700	J*	23500	385	—	157	137
10700	11500	K*	25000	385	—	157	142
11500	12400	L*	26500	385	—	162	147
12400	1340	M*	29000	385	—	—	152
13400	14600	N*	31500	385	—	—	157
14600	16000	O*	34500	385	—	—	162

NOTES

1. Consideration will be given to the acceptance of equipment differing from these requirements on units which are classed for restricted service (generally those with geographical limitations ensuring service in sheltered or shallow waters only).

2. Special consideration will be given to units which are unmanned during towed voyages and transfer moves.

1.5 High holding power anchors

1.5.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass.

1.5.2 If approval is sought for a range of sizes, then at least two sizes are to be tested. The smaller of the two anchors is to have a mass not less than one tenth of that of the larger anchor, and the larger of the two anchors tested is to have a mass not less than one tenth of that of the largest anchor for which approval is sought.

1.5.3 The tests are to be conducted on not less than three different types of bottom, which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

1.5.4 The test should normally be carried out from a tug, and the pull measured by dynamometer or derived from recently verified curves of tug rev/min against bollard pull. A scope of 10 is recommended for the anchor cable, which may be wire rope for this test, but in no case should a scope of less than six be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

1.5.5 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by *Pt 4, Ch 9, 1.5 High holding power anchors 1.5.1*, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

1.6 Chain cables

1.6.1 The minimum sizes and lengths of chain cables are to be as required by *Pt 4, Ch 9, 1.4 Anchors 1.4.6*.

1.6.2 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials and are to be graded in accordance with *Pt 4, Ch 9, 1.6 Chain cables 1.6.2*.

Table 9.1.2 Anchor equipmant chain grades

Grade	Material	Tensile strength	
		N/mm^2	kgf/mm^2
U1	Mild steel	300–490	(31–50)
U2(a)	Special quality steel (wrought)	490–690	(50–70)

U2(b)	Special quality steel (cast)	490–690	(50–70)
U3	Extra special quality steel	690 min.	(70 min.)

1.6.3 Grade U1 material having a tensile stress of less than 400 N/mm^2 (41 kgf/cm^2) is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

1.6.4 The form and proportion of links and shackles are to be in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

1.6.5 As an alternative to the chains listed in *Pt 4, Ch 9, 1.4 Anchors 1.4.6*, consideration will be given to the use of the following:

- Chain cables of Grades R3, R3S and R4 in accordance with *Ch 10, 3 Stud link mooring chain cables* of the Rules for Materials.
- Wire rope meeting the requirements of the Rules for Materials.

In this case, the length and breaking strength of the wire rope will be specially considered.

1.7 Arrangements for working and stowing anchors and cables

1.7.1 A windlass or winch of sufficient power and suitable for the type of cable is to be provided for each of the anchor cables. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass or winch power.

1.7.2 The windlasses or winches are to be securely fitted and efficiently bedded to suitable positions on the unit. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

1.7.3 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:

36,79 d_c^2 N (3,75 d_c^2 kgf) – for Grade U1 chain,

41,68 d_c^2 N (4,25 d_c^2 kgf) – for Grade U2 chain,

41,6 d_c^2 N (4,75 dd_c^2 kgf) – for Grade U3 chain,

where d_c is the chain diameter, in mm.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:

(i) short-term pull:

1,5 times the continuous duty pull as defined in *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.3*.

(ii) anchor breakout pull:

$$16{,}24\,W_a + \frac{14{,}0 l_c d_c^2}{100}\ \text{N}$$

$$\left(1{,}65 W_a + \frac{14{,}2 l_c d_c^2}{1000}\ \text{kgf}\right)$$

where

l_c is length of chain cable per anchor, in metres, as given by *Pt 4, Ch 9, 1.4 Anchors 1.4.6*

W_a is the mass of high holding power anchor, in kg, as given in *Pt 4, Ch 9, 1.4 Anchors 1.4.6*

(c) The windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

$K_b d_c^2$ (44 – 0,08 d_c) N

$K_b d_c^2$ (44 – 0,08 d_c) kgf)

where

K_b is given in *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.3*.

NOTE

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's *Type Approval Scheme* will not require shop testing on an individual basis.

Cable grade	K_b	
	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41 (0,45)	7,85 (0,8)
U2	6,18 (0,63)	11,0 (1,12)
U3	8,83 (0,9)	15,7 (1,6)

1.7.4 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.3* are to be submitted, together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

1.7.5 During trials on board the unit, the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of not less than 9 m/min. Where the depth of water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

1.7.6 The cable is to be capable of being paid out in the event of a power failure.

1.7.7 Windlass performance characteristics specified in *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.3* and *Pt 4, Ch 9, 1.7 Arrangements for working and stowing anchors and cables 1.7.5* are based on the following assumptions:

- One cable lifter only is connected to the drive shaft.
- Continuous duty and short-term pulls are measured at the cable lifter.
- Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
- The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
- Hawse pipe efficiency assumed to be 70 per cent.

1.7.8 An easy lead of the cables from the windlass or winch to the anchors and chain lockers or wire storage drum is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

1.7.9 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. If more than one chain is to be stowed in one locker then the individual cables are to be separated by substantial divisions in the locker.

1.7.10 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN (6,5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped in an emergency from an accessible position outside the chain locker.

1.7.11 Where wire rope cables are used, these are to be stored on suitable drums. The lead to the drums is to be such that the cables will reel onto the drums reasonably evenly. If the drums are designed to apply the full winch hauling load to the cables then the arrangements, using spooling gear or otherwise, are to ensure even reeling of the cables onto the drums.

1.7.12 Fairleads, hawse pipes, anchor racks and associated structure and components are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The plating and framing in way of these components are to be reinforced as necessary. Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc. are to be suitably strengthened.

1.7.13 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

- a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe;
- access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe if the sea is liable to break over the windlass; and
- for column-stabilised units, *see Pt 4, Ch 7, 4.7 Weathertight integrity related to stability 4.7.2*.

1.7.14 All anchors are to be stowed to prevent moving during transit.

1.8 Testing of equipment

1.8.1 All anchors and chain cables are to be tested at establishments and on machines recognised by LR and under the supervision of LR's Surveyors or other Officers recognised by LR, and in accordance with the Rules for Materials.

1.8.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the unit.

1.8.3 Steel wire ropes are to be tested as required by the Rules for Materials.

■ *Section 2*
Towing arrangements

2.1 General

2.1.1 All non-self-propelled units which are to be wet-towed to their operating location are to be fitted with adequate arrangements for towing.

2.1.2 Plans and full particulars of the unit's towing facilities are to be submitted for approval, together with calculations or model test data supporting the assigned system design load. The maximum permitted static bollard pull for each towing arrangement is to be stated on the plans.

2.1.3 Oil storage units which may be towed in order to avoid hazards or extreme environmental conditions may require emergency towing arrangements in accordance with IMO Resolution MSC 35(63) for oil tankers when required by a National Administration. Where emergency towing arrangements are required, plans of the system and structural arrangements are to be submitted for approval. *See also Pt 3, Ch 13, 9 Mooring of ships at single point moorings* of the *Rules and Regulations for the Classification of Ships*.

2.2 Towing system

2.2.1 Units are to be provided with a main towing system suitable for towing with one or two towing vessels and in addition it is recommended that an emergency towing system is provided.

2.2.2 The emergency towing system may be arranged by using the unit's anchor line or similar system.

2.2.3 The main towing system is to be suitable for the design load in accordance with *Pt 4, Ch 9, 2.1 General 2.1.2* but is not to be taken less than 75 tonne-f.

2.2.4 The components of the towing system are to be manufactured and tested in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

2.2.5 The main towing system is to consist of not less than the following parts:

- Two attachments to the unit (e.g. towing brackets).

- Two chain/wire rope pendants connected to the unit.
- One triangular plate or equivalent.
- Two wire rope towlines as 'weak links'.
- Shackles for connections.

2.2.6 Wire ropes are to have 'hard eyes' fitted at their ends.

2.2.7 Where towing bridles can be subjected to heavy wear due to chafing, chains are to be used.

2.2.8 The attachments to the unit are to be as far apart as practicable and on column-stabilised units the attachments are to be fitted to the lower hulls.

2.2.9 The length of the towing pendants attached to the unit is not to be less than the distance between the attachments.

2.2.10 The position and arrangement of the towing attachments are to be such that it is possible to change the chain/wire towing pendant connections quickly in calm water.

2.2.11 When towing with two towing vessels, each towline (weak link) is to be fitted between the unit's towing pendants and the towlines of the towing vessels. When towing with one towing vessel, the towline (weak link) is to be connected between the triangular plate or equivalent and the towline of the towing vessel.

2.2.12 The length of each towline (weak link) is, in general, not to be less than 50 m so that the connection to the towline of the towing vessel is at a safe distance from the unit.

2.3 Strength

2.3.1 Each towing pendant connected to the unit is to have a minimum breaking strength of three times the design load, *see Pt 4, Ch 9, 2.2 Towing system 2.2.3*.

2.3.2 The towline (weak link) is to have a breaking strength of approximately 85 per cent of the breaking strength of the towing pendant connected to the unit.

2.3.3 The towing pendant connections to the unit, triangular plate and shackles are to have a breaking strength greater than the strongest part of the towing system.

2.3.4 The attachments to the unit are to be designed for a towing direction of 0° to 90° off centreline port and starboard. Account is to be taken of the specified range of inclination angles.

2.3.5 Towing brackets or pad-eyes and their support structure are to be designed to the breaking strength of the attached towing pendant. The permissible stresses are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*.

2.4 Retrieval system

2.4.1 Means are to be provided to retrieve the unit's towing pendants or bridle in the event that the towing vessel's towline or the towline (weak link) should break.

2.5 Spare parts

2.5.1 It is recommended that an adequate number of spare parts for the towing system be provided on board during towing operations.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the unit types detailed in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*, and requirements are given for rudders, nozzles, steering gear, tunnel thrust unit structure and stabiliser structure.

1.1.2 Where units are fitted with conventional rudders, the scantlings and arrangements are to comply with the requirements of this Chapter.

1.1.3 Where a self-propelled unit is fitted with a non-conventional rudder or the rudder is omitted, special consideration will be given to the steering system so as to ensure that an acceptable degree of reliability and effectiveness is provided in order to achieve equivalence to the normal Rule requirements.

1.2 General symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

1.2.2 *L, B,* C_{b} as defined in *Pt 4, Ch 1, 5.1 General*

σ_0 = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 (kgf/mm^2)

k = higher tensile steel factor, *see Pt 4, Ch 2, 1.2 Steel*.

1.3 Navigation in ice

1.3.1 Where an ice class notation is included in the class of a unit, additional requirements are applicable as detailed in *Pt 3, Ch 6 Units for Transit and Operation in Ice*.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 Requirements for rudders are given in *Pt 3, Ch 13, 2 Rudders* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

2.1.2 Where an **OIWS** (In-water Survey) notation is to be assigned, *see also Pt 4, Ch 2, 2.4 Ship units and other surface type units*, means are to be provided for ascertaining the rudder pintles and bush clearances and for verifying the security of the pintles in their sockets with the unit afloat.

2.1.3 When a ship unit is to be converted and classed as a floating offshore installation and the rudder is inoperative, it is strongly recommended that the rudder be removed to prevent damage to the steering gear in storm conditions.

2.1.4 If the rudder is removed in accordance with *Pt 4, Ch 10, 2.1 General 2.1.3*, the hull aperture is to be fitted with a suitable blanking plate and sealing arrangements to ensure watertight integrity of the hull. The scantlings and arrangements are to comply with *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*.

2.1.5 Where rudders are left in situ on ship units *see Pt 5, Ch 19, 1.1 Application 1.1.3*.

2.1.6 The machinery and equipment is to be subject to survey in accordance with the requirements of *Pt 1, Ch 3 Periodical Survey Regulations*.

■ *Section 3*
Fixed and steering nozzles

3.1 General

3.1.1 Requirements for fixed and steering nozzles are given in *Pt 3, Ch 13, 3 Fixed and steering nozzles* of the Rules for Ships, which should be complied with.

■ *Section 4*
Steering gear and allied systems

4.1 General

4.1.1 Requirements for steering gear are given in *Pt 5, Ch 19 Steering Gear*.

4.1.2 When units are fitted with steering arrangements consisting of Azimuth thrusters, *see Pt 5, Ch 20 Azimuth Thrusters*.

■ *Section 5*
Tunnel thrust unit structure

5.1 General

5.1.1 Requirements for tunnel thrust unit structure are given in *Pt 3, Ch 13, 5 Bow and stern thrust unit structure* of the Rules for Ships, which should be complied with.

5.1.2 Thrust units are to be enclosed in suitable watertight spaces to prevent flooding in the case of leakage or damage to the thrust unit.

■ *Section 6*
Stabiliser structure

6.1 General

6.1.1 Requirements for stabiliser structure are given in *Pt 3, Ch 13, 6 Stabiliser structure* of the Rules for Ships, which should be complied with.

■ *Section 1* General

1.1 Definitions

1.1.1 **Quality Assurance Scheme**. LR's Quality Assurance requirements for the hull construction of mobile offshore units are defined as follows:

(a) **Quality Assurance**. All activities and functions concerned with the attainment of quality including documentary evidence to confirm that such attainment is met.
(b) **Quality system**. The organisation structure, responsibilities, activities, resources and events laid down by Management that together provide organised procedures (from which data and other records are generated) and methods of implementation to ensure the capability of the fabrication yard to meet quality requirements.
(c) **Quality programme**. A documented set of activities, resources and events serving to implement the quality system of an organisation.
(d) **Quality plan**. A document derived from the quality programme setting out the specific quality practices, special processes, resources and activities relevant to a particular unit or series of similar units. This document will also indicate the stages at which, as a minimum, direct survey and/or system monitoring will be carried out by the Classification Surveyor.
(e) **Quality control**. The operational techniques and activities used to measure and regulate the quality of construction to the required level.
(f) **Inspection**. The process of measuring, examining, testing, gauging or otherwise comparing the item with the approved drawings and the fabrication yard's written standards, including those which have been agreed by LR for the purposes of classification of the specific type of unit concerned.
(g) **Assessment**. The initial comprehensive review of the fabrication yard's quality systems, prior to the granting of approval, to establish that all the requirements of these Rules have been met.
(h) **Audit**. A documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality programme continue to be effectively implemented.
(i) **Hold point**. A defined stage of manufacture beyond which the work must not proceed until the inspection has been carried out by all the relevant personnel.
(j) **System monitoring**. The act of checking, on a regular basis, the applicable processes, activities and associated documentation that the Fabricator's quality system continues to operate as defined in the quality programme.
(k) **Special process**. A process where some aspects of the required quality cannot be assured by subsequent inspection of the processed material alone. Manufacturing special processes include welding, forming and the application of protective treatments. Inspection and testing processes classified as special processes include non-destructive examination and pressure and leak testing.

1.2 Scope of the Quality Assurance Scheme

1.2.1 This Chapter specifies the minimum Quality system requirements for a fabrication yard to construct offshore units under LR's *Quality Assurance Scheme*.

1.2.2 For the purposes of this Chapter of the Rules, 'construction (hull)' comprises the primary bracings, columns, legs, footings, hull structure, appendages, superstructure, deckhouses and closing appliances, all as required by the Rules.

1.2.3 Although the requirements of this scheme are, in general, for steel structures of all welded construction, other materials for use in hull construction will be considered.

■ *Section 2* Application

2.1 Certification of the fabrication yard

2.1.1 Requirements for application are given in *Pt 3, Ch 15, 2 Application* of the Rules for Ships, which should be complied with.

■ *Section 3* Particulars to be submitted

3.1 Documentation and procedures

3.1.1 Requirements for particulars to be submitted are given in *Pt 3, Ch 15, 3 Particulars to be submitted* of the Rules for Ships, which should be complied with.

■ *Section 4* Requirements of Parts 1 and 2 of the Scheme

4.1 General

4.1.1 Requirements for Parts 1 and 2 of the scheme are given in *Pt 3, Ch 15, 4 Requirements of Parts 1 and 2 of the Scheme* of the Rules for Ships, which should be complied with.

■ *Section 5* Additional requirements for Part 2 of the Scheme

5.1 Quality System procedures

5.1.1 Additional requirements for Part 2 of the scheme are given in *Pt 3, Ch 15, 5 Additional requirements for Part 2 of the Scheme* of the Rules for Ships, which should be complied with.

Section 6
Initial assessment of fabrication yard

6.1 General

6.1.1 Requirements for the initial assessment of the Shipyard are given in *Pt 3, Ch 15, 6 Initial assessment of the shipyard* of the Rules for Ships, which should be complied with.

Section 7
Approval of the fabrication yard

7.1 General

7.1.1 Requirements for approval of the shipyard are given in *Pt 3, Ch 15, 7 Approval of the shipyard* of the Rules for Ships, which should be complied with.

Section 8
Maintenance of approval

8.1 General

8.1.1 Requirements for maintenance of approval are given in *Pt 3, Ch 15, 8 Maintenance of approval* of the Rules for Ships, which should be complied with.

Section 9
Suspension or withdrawal of approval

9.1 General

9.1.1 Requirements for suspension or withdrawal of approval are given in *Pt 3, Ch 15, 9 Suspension or withdrawal of approval* of the Rules for Ships, which should be complied with.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Appendix contains details of acceptable design S-N curves and joint classification. The details contained in this Appendix take due account of the fatigue data published in the *UK HSE Guidance Notes for Design, Construction and Classification of Offshore Installations*, 4th edition, 1990.

1.1.2 All tubular joints are assigned Class T. Other types of joints are assigned Class B, C, D, E, F, F2, G or W depending upon:

- geometric arrangements;
- direction of applied stress; and
- method of fabrication and inspection.

1.1.3 Details of the design S-N curves are given in *Pt 4, Ch 12, 2 Fatigue design S-N curves*, joint classifications are given in *Pt 4, Ch 12, 3 Fatigue joint classification*.

1.1.4 Guidance on the determination of global stress concentration factors is given in *Pt 4, Ch 12, 4 Stress concentration factors*.

1.1.5 Other methods may be used after special consideration and agreement with LR. Detailed proposals are to be submitted.

■ *Section 2* Fatigue design S-N curves

2.1 Basic design S-N curves

2.1.1 The basic design curves consist of linear relationships between $\log(S_B)$ and $\log(N)$. They are based upon a statistical analysis of appropriate experimental data and may be taken to represent two standard deviations below the mean line. Thus the basic S-N curves are of the form:

$$\log(N) = \log(K_1) - d\sigma - m\log(S_B)$$

where

N = the predicted number of cycles to failure under stress range S_B

K_1 = a constant relating to the mean S-N curve

d = the number of standard deviations below the mean

σ = the standard deviation of $\log N$

m = the inverse slope of the S-N curve.

The relevant values of these terms are shown in *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.3*. *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.3* also shows the value of K_2

where

log(K_2) = log(K_1) – 2σ

which is relevant to the basic design curves (i.e. for d = 2).

2.2 Modifications to basic S-N curves

2.2.1 The factors listed in this sub-Section are to be considered when using the basic S-N curve.

2.2.2 **Unprotected joints in sea-water**. For joints without adequate corrosion protection which are exposed to sea water the basic S-N curve is reduced by a factor of two on life for all joint classes.

NOTE

For high strength steels, i.e. σ_{y} >400 N/mm^2, a penalty factor of two may not be adequate. In addition the correction relating to the numbers of small stress cycles is not applicable.

2.2.3 **Effect of plate thickness.** The fatigue strength of welded joints is to some extent dependent on plate thickness, strength decreasing with increasing thickness. The basic S-N curves shown in *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.5*and *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.5* relate to thicknesses as follows:

- Nodal joints (Class T) up to 32 mm
- Non-nodal joints (Classes B-G) up to 22 mm.

For joints of other thicknesses, correction factors on life or stress have to be applied to produce a relevant S-N curve. The correction on stress range is of the form:

$$S = S_{\text{B}}\left(\frac{t_{\text{B}}}{t}\right)^{1/4}$$

where

S = the fatigue strength of the joint under consideration

S_{B} = the fatigue strength of the joint using the basic S-N curve

t = the actual thickness of the member under consideration

t_{B} = the thickness relevant to the basic S-N curve

Substituting the above relationship in the basic S-N curve equation in *Pt 4, Ch 12, 2.1 Basic design S-N curves 2.1.1* and using the equation for log(K_2) in *Pt 4, Ch 12, 2.1 Basic design S-N curves 2.1.1* yields the following equation of the S-N for a joint member thickness t:

$$\log(N) = \log K_2 - m \log\left(\frac{S}{\left(\frac{t_{\text{B}}}{t}\right)^{1/4}}\right)$$

A value of t = 22 mm should be used for calculating endurance N when the actual thickness is less than 22 mm.

NOTE

This gives a benefit for nodal joints with wall thicknesses in the range of 22 to 32 mm.

Table 12.2.1 Details of basic S-N curves

Class	K_1	K_1		m	Standard deviation	K_2	S_o	
		log_{10}	log_e		log_{10}		N/mm^2	log_e
B	2,343 x 10^{15}	15,3697	35,3900	4,0	0,1821	0,4194	1,01 x 10^{15}	100
C	1,082 x 10^{14}	14,0342	32,3153	3,5	0,2041	0,4700	4,23 x 10^{13}	78
D	3,988 x 10^{12}	12,6007	29,0144	3,0	0,2095	0,4824	1,52 x 10^{12}	53
E	3,289 x 10^{12}	12,5169	28,8216	3,0	0,2509	0,5777	1,04 x 10^{12}	47
F	1,289 x 10^{12}	12,2370	28,1770	3,0	0,2183	0,5027	0,63 x 10^{12}	40
F2	1,231 x 10^{12}	12,0900	27,8387	3,0	0,2279	0,5248	0,43 x 10^{12}	35
G	0,566 x 10^{12}	11,7525	27,0614	3,0	0,1793	0,4129	0,25 x 10^{12}	29
W	0,368 x 10^{12}	11,5662	26,6324	3,0	0,1846	0,4251	0,16 x 10^{12}	25
T	4,577 x 10^{12}	12,6606	29,1520	3,0	0,2484	0,5720	1,46 x 10^{12}	53, *see* Note 1

NOTES

1. Idealised hot spot stress

2. For example, the T curve expressed in terms of log_{10} is:

log_{10} (N) = 12,6606 – 0,2484d – 3 log_{10} (S_B)

2.2.4 **Weld improvement**. For welded joints involving potential fatigue cracking from the weld toe, an improvement in strength by at least 30 per cent, equivalent to a factor of 2,2 on life, can be obtained by controlled local machining or grinding of the weld toe. This is to be carried out either with a rotary burr or by disc grinding. The treatment should produce a smooth concave profile at the weld toe with the depth of the depression penetrating into the plate surface to at least 0,5 mm below the bottom of any visible undercut, *see Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.5*, and ensuring that no exposed defects remain. The maximum depth of local machining or grinding is not to exceed 2 mm or five per cent of the plate thickness. In the case of a multi-pass weld more than one weld toe may need to be dressed. Where toe grinding is used to improve the fatigue life of fillet welded connections, care should be taken to ensure that the required throat size is maintained. The benefit of grinding is only applicable for welded joints which are adequately protected from sea-water corrosion. Any credit for other beneficial treatments should be justified. It is recommended that no advantage for toe grinding should be taken at the initial design stage. Overall weld profiling is preferred but no improvement in fatigue strength can be allowed unless accompanied by toe grinding. In the case of partial penetration welds, where failure may occur from the weld root, grinding of the weld toe cannot be relied upon to give an increase in strength.

2.2.5 Special consideration will be given to alternative techniques intended to improve weld quality. Detailed proposals are to be submitted.

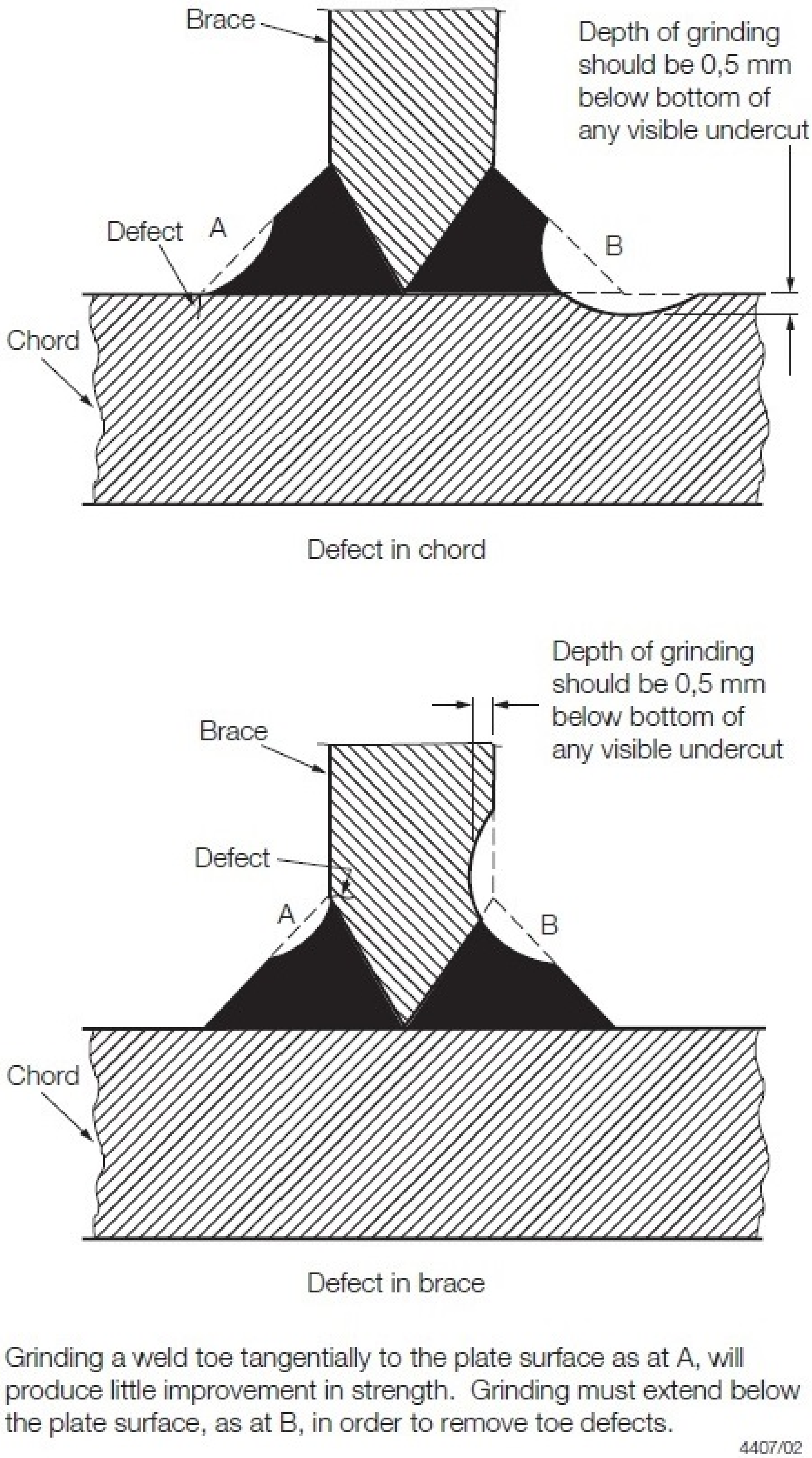


Figure 12.2.1 Weld improvements

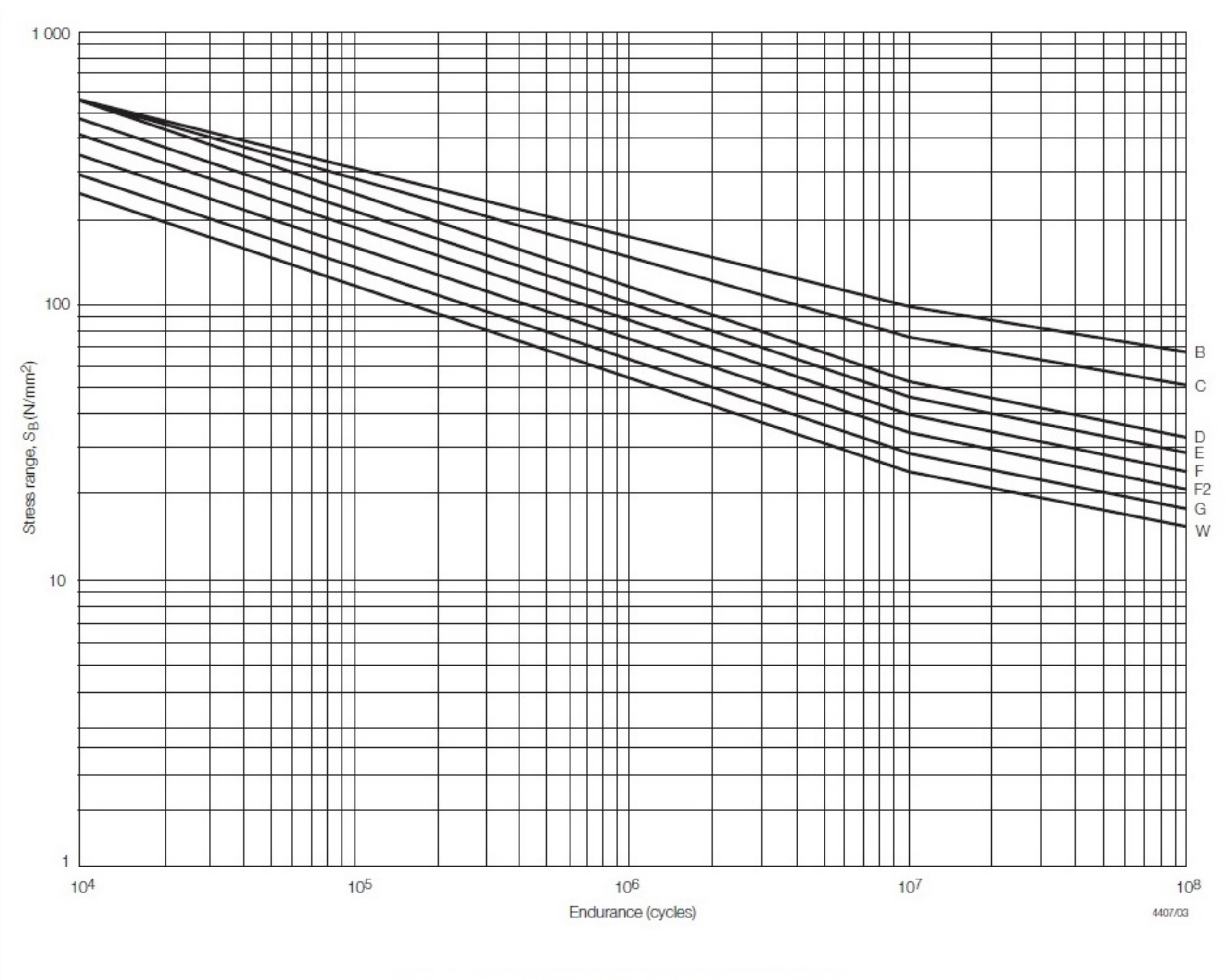


Figure 12.2.2 Basic design S-N curve for non-nodal joints

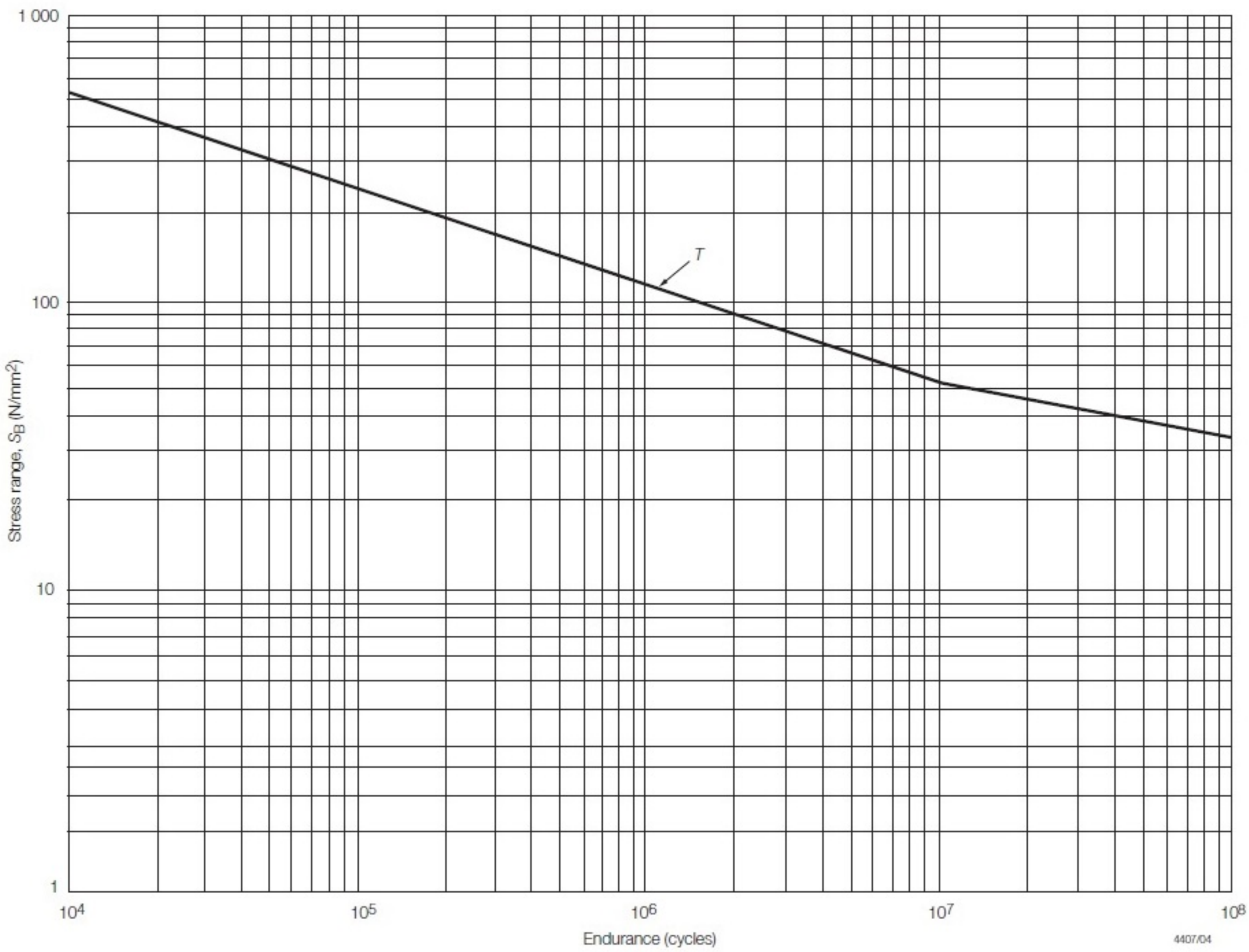


Figure 12.2.3 Basic design S-N curve for nodal joints

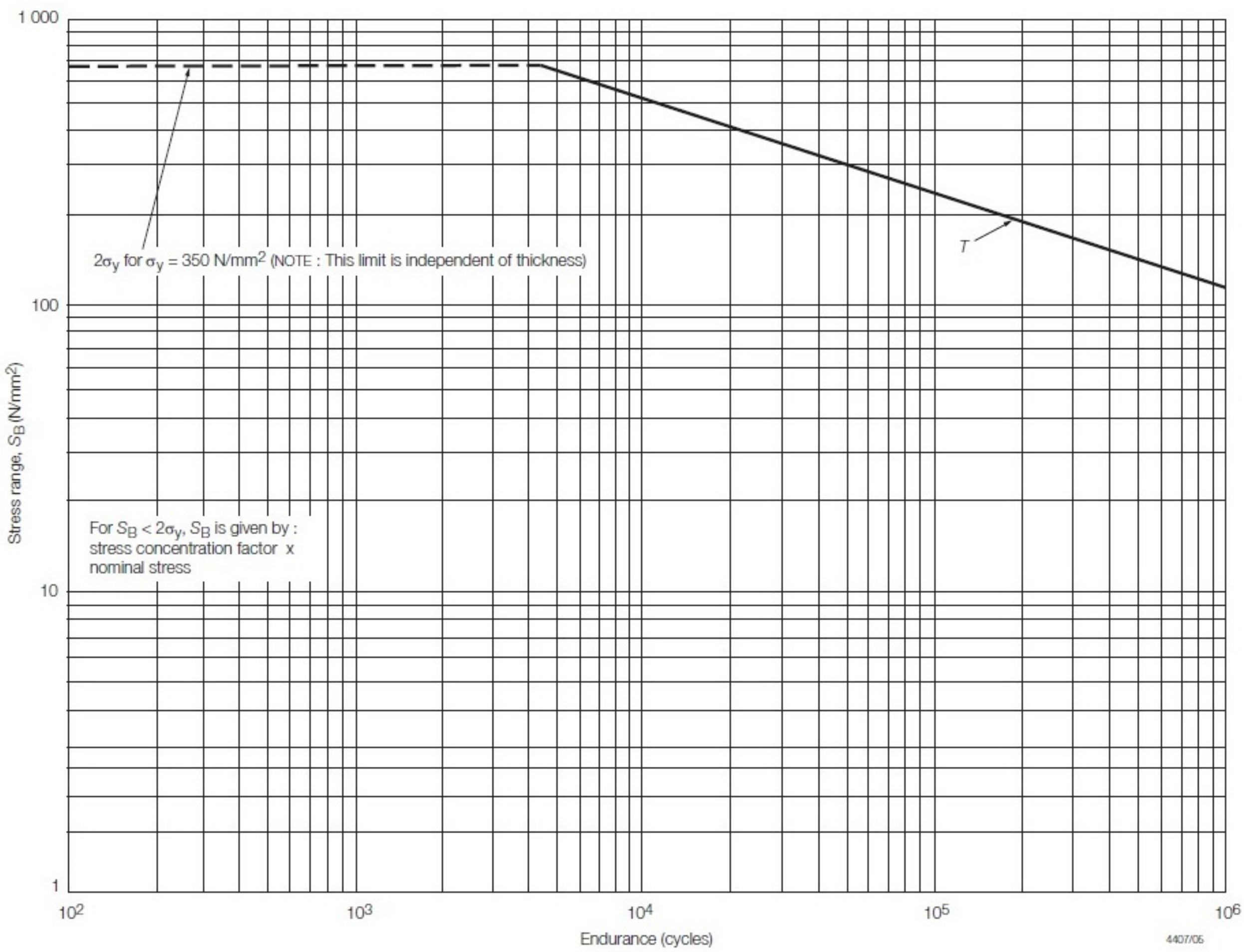


Figure 12.2.4 Treatment of high cyclic stresses for the T-curve and a material with yield stress = 350 N/mm^2

2.3 Treatment of low stress cycles

2.3.1 Under constant amplitude stresses there is a certain stress range, which varies both with the environment and with the size of any initial defects, below which an indefinitely large number of cycles can be sustained. In air and sea-water with adequate protection against corrosion, and with details fabricated in accordance with this Appendix, it is assumed that this non-propagating stress range, S_o . is the stress corresponding to $N = 10^7$ cycles; relevant values of S_o are shown in *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.3*.

2.3.2 When the applied fluctuating stress has varying amplitude, so that some of the stress ranges are greater and some less than S_o , the larger stress ranges will cause growth of the defect, thereby reducing the value of the non-propagating stress range below S_o . In time, an increasing number of stress ranges, below S_o can themselves contribute to crack growth. The final result is an earlier fatigue failure than could be predicted by assuming that all stress ranges below S_o are ineffective.

2.3.3 An adequate estimate of this behaviour can be made by assuming that the S-N curve has a change of inverse slope from m to m + 2 at $N = 10^7$ cycles. This correction does not apply in the case of unprotected joints in sea-water.

2.4 Treatment of high stress cycles

2.4.1 For high stress cycles the design S-N curve for nodal joints (the T curve) may be extrapolated back linearly to a stress range equal to twice the material yield stress $2\,\sigma_y$.

2.4.2 An example of the high stress cycle limit for the T curve is given in *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.5*.

2.4.3 A similar procedure can be adopted for non-nodal joints (Classes B-G) where local bending or other structural stress concentrating features are involved and the relevant stress range includes the stress concentration.

2.4.4 If the joint is in a region of simple membrane stress then the design S-N curves may be extrapolated back linearly to a stress range given by twice the tensile stress limitations given in these Rules.

2.4.5 For the Class W curve, extrapolation may be made back as for the non-nodal joints but to a stress range defined by half the values given above (i.e. with reference to shear instead of tensile stress).

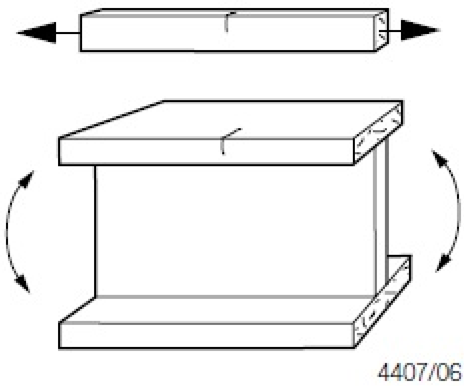
■ *Section 3*
Fatigue joint classification

3.1 General

3.1.1 Fatigue joint classification details including notes on mode of failure and typical examples are given in *Pt 4, Ch 12, 3.1 General 3.1.1*.

Table 12.3.1 Fatigue joint classification

Type number, description and notes on mode of failure	Class explanatory comments	Examples, including failure modes
TYPE 1 MATERIAL FREE FROM WELDING		
Notes on potential modes of failure:		
In plain steel, fatigue cracks initiate at the surface, usually either at surface irregularities or at corners of the cross-section. In welded construction, fatigue failure will rarely occur in a region of plain material since the fatigue strength of the welded joints will usually be much lower. In steel with rivet or bolt holes or other stress concentrations arising from the shape of the member, failure will usually initiate at the stress concentration.		
1.1 Plain steel		

(a) In the as-rolled condition, or with cleaned surfaces but with no flame-cut edges of re-entrant corners.	B Beware of using Class B for a member which may acquire stress concentration during its life, e.g. as a result of rust pitting. In such an event Class C would be more appropriate.	
(b) As (a) but with any flame-cut edges subsequently ground or machined to remove all visible sign of the drag lines.	B Any re-entrant corners in flame-cut edges should have a radius greater than the plate thickness.	
(c) As (a) but with the edges machine flame cut by a controlled procedure to ensure that the cut surface is free from cracks.	C Note, however, that the presence of a re-entrant corner implies the existence of a stress concentration so that the design stress should be taken as the net stress multiplied by the relevant stress concentration factor.	

TYPE 2 CONTINUOUS WELDS ESSENTIALLY PARALLEL TO THE DIRECTION OF APPLIED STRESS

Notes on potential modes of failure:

With the excess weld metal dressed flush, fatigue cracks would be expected to initiate at weld defect locations. In the as-welded condition, cracks might initiate at stop-start positions or, if these are not present, at weld surface ripples.

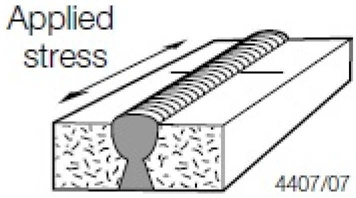
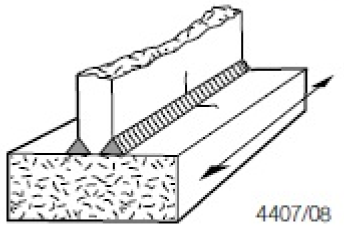
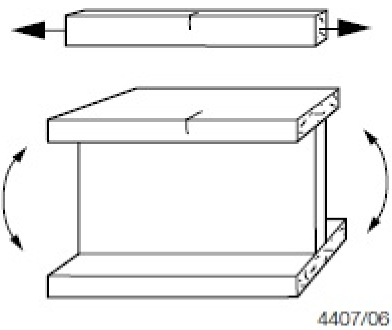
General comments:

(a) Backing strips:

If backing strips are used in making these joints: (i) they must be continuous; and (ii) if they are attached by welding those welds must also comply with the relevant Class requirements (note particularly that tack welds, unless subsequently ground out or covered by a continuous weld, would reduce the joint to Class F, *see* joint 6.5).

(b) Edge distance:

Edge distance: An edge distance criterion exists to limit the possibility of local stress concentrations occurring at unwelded edges as a result for example, of undercut, weld spatter or accidental overweave in manual fillet welding (*see also* notes on joint Type 4). Although an edge distance can be specified only for the 'width' direction of an element, it is equally important to ensure that no accidental undercutting occurs on the unwelded corners of, for example, cover plates or box girder flanges. If it does occur it should subsequently be ground smooth.

2.1 Full or partial penetration butt welds, or fillet welds. Parent or weld metal in members, without attachments built up of plates or sections, and joined by continuous welds.		
(a) Full penetration butt welds with the weld overfill dressed flush with the surface and finish-machined in the direction of stress, and with the weld proved free from significant defects by non-destructive examination.	B The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	
(b) Butt or fillet welds with the welds made by an automatic submerged or open arc process and with no stop-start positions within the length.	C If an accidental stop-start occurs in a region where Class C is required remedial action should be taken so that the finished weld has a similar surface and root profile to that intended.	
(c) As (b) but with the weld containing stopstart positions within the length.	D For situation at the ends of flange cover plates see joint Type 6.4.	

TYPE 3 TRANSVERSE BUTT WELDS IN PLATES (i.e. essentially perpendicular to the direction of applied stress)

Notes on potential modes of failure:

With the weld ends machined flush with the plate edges, fatigue cracks in the as-welded condition normally initiate at the weld toe, so that the fatigue strength depends largely upon the shape of the weld overfill. If this is dressed flush the stress concentration caused by it is removed and failure is then associated with weld defects. In welds made on a permanent backing strip, fatigue cracks initiate at the weld metal/strip junction and in partial penetration welds (which should not be used under fatigue conditions), at the weld root.

Welds made entirely from one side, without a permanent backing, require care to be taken in the making of the root bead in order to ensure a satisfactory profile.

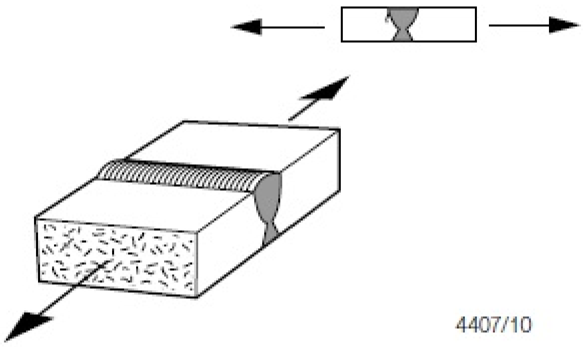
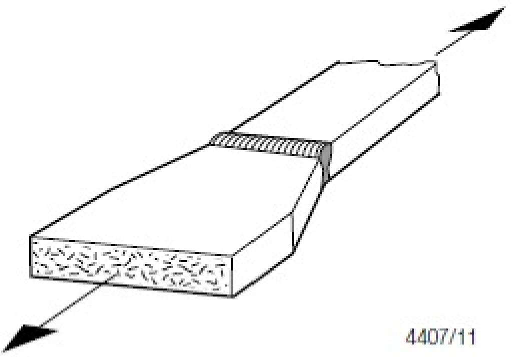
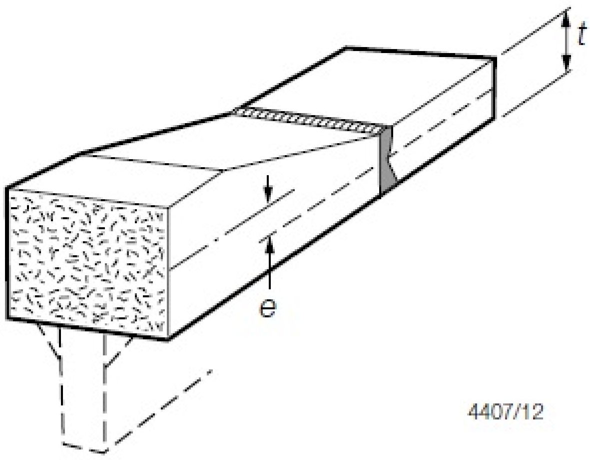
Design stresses:

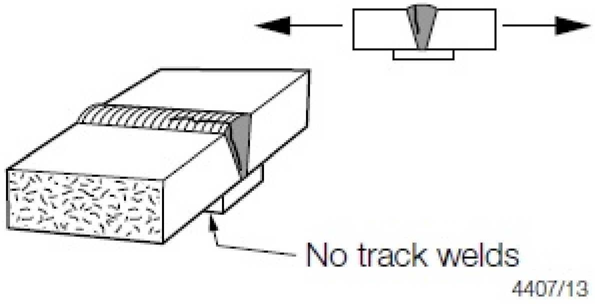
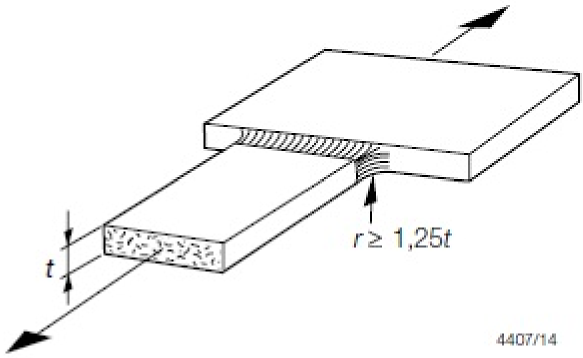
In the design of butt welds of Types 3.1 or 3.2 which are not aligned, the stresses must include the effect of any eccentricity. An approximate method of allowing for eccentricity in the thickness direction is to multiply the normal stress by ($1 + 3\,\frac{e}{t}$), where

e is the distance between centres of thickness of the two abutting members: if one of the members is tapered, the centre of the untapered thickness must be used; and

t is the thickness of the thinner member.

With connections which are supported laterally, e.g. flanges of a beam which are supported by the web, eccentricity may be neglected.

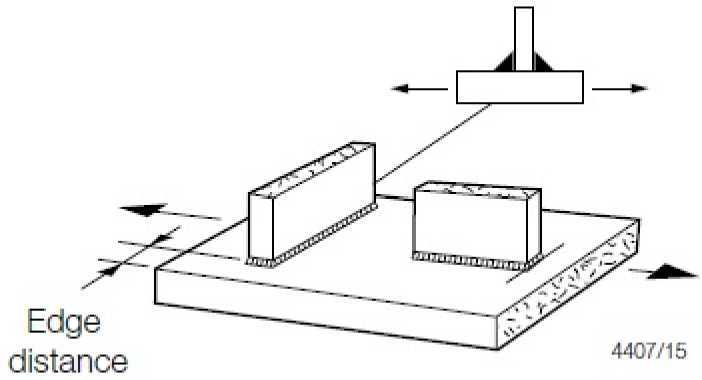
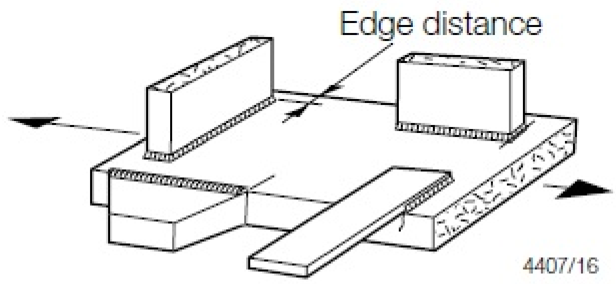
3.1 Parent metal adjacent to or weld metal in full penetration butt joints welded from both sides between plates of equal width and thickness or where differences in width and thickness are machined to a smooth transition not steeper than 1 in 4.	Note that this includes butt welds which do not completely traverse the member, such as circular welds used for inserting infilling plates into temporary holes.	
(a) With the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.	C The significance of defects should be determine with the aid of specialist advice and/or by the use of fracture mechanic analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	 4407/10
(b) With the welds made, either manually or by an automatic process, other than submerged arc, provided all runs are made in the downhand position.	D In general, welds made by the submerged arc process, or in positions other than downhand, tend to have a poor reinforcement shape, from the point of view of fatigue strength. Hence such welds are downgraded from D to E.	 4407/11
(c) Welds made other than in (a) or (b).	E In both (b) and (c) of the corners of the cross-section of the stressed element at the weld toes should be dressed to a smooth profile. Note that step changes in thickness are in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining. Step changes in width lead to large reductions in strength (*see* joint Type 3.3).	 4407/12

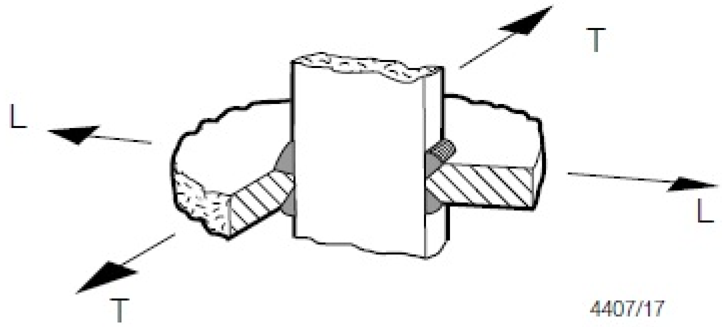
3.2 Parent metal adjacent to, or weld metal in, full penetration butt joints made on a permanent backing strip between plates of equal width and thickness or with differences in width and thickness machined to a smooth transition not steeper than 1 in 4.	F Note that if the backing strip is fillet welded or tack welded to the member the joint could be reduced to Class G (joint Type 4.2).	
3.3 Parent metal adjacent to, or weld metal in, full penetration butt welded joints made from both sides between plates of unequal width, with the weld ends ground to a radius not less than 1,25 times the thickness *t*.	F2 Step changes in width can often be avoided by the use of shaped transition plates, arranged so as to enable butt welds to be made between plates of equal width. Note that for this detail the stress concentration has been taken into account in the joint classification.	

TYPE 4 WELDED ATTACHMENTS ON THE SURFACE OR EDGE OF A STRESSED MEMBER

Notes on potential modes of failure:

When the weld is parallel to the direction of the applied stress, fatigue cracks normally initiate at the weld ends, but when it is transverse to the direction of stressing they usually initiate at the weld toe; for attachments involving a single, as opposed to a double, weld cracks may also initiate at the weld root. The cracks then propagate into the stressed member. When the welds are on or adjacent to the edge of the stressed member the stress concentration is increased and the fatigue strength is reduced, this is the reason for specifying an 'edge distance' in some of these joints (*see also* note on edge distance in joint Type 2).

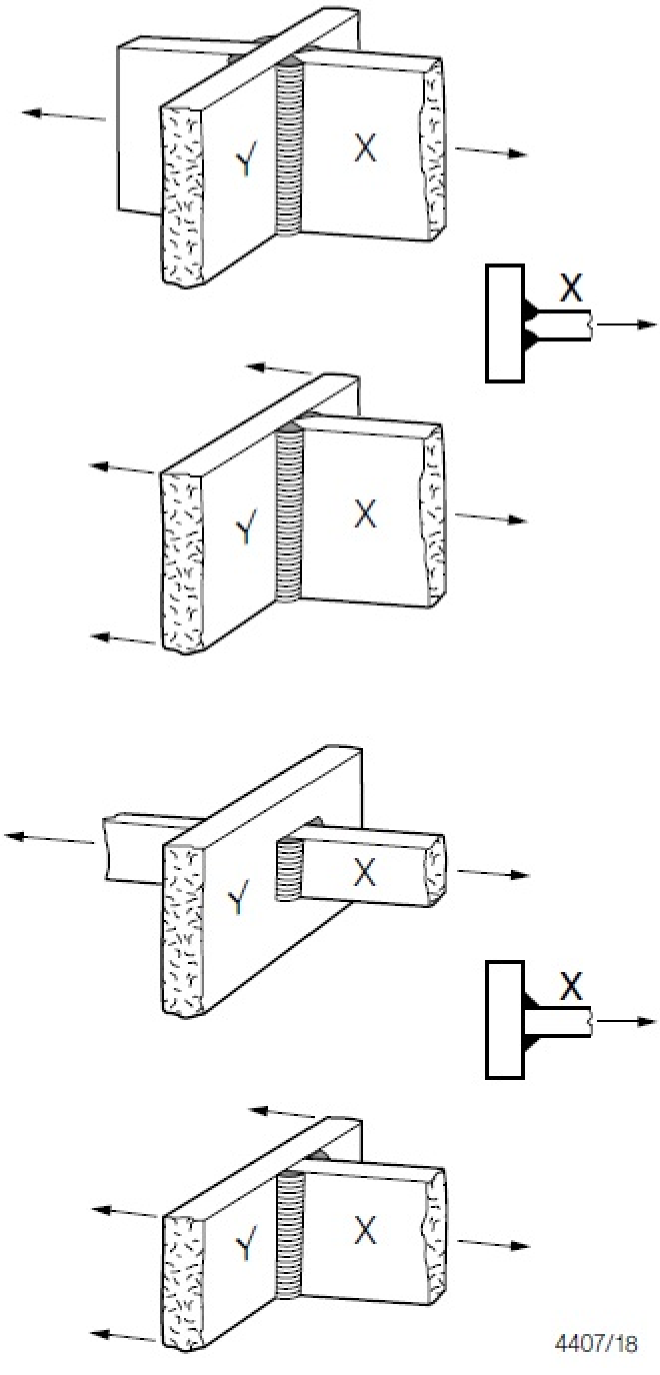
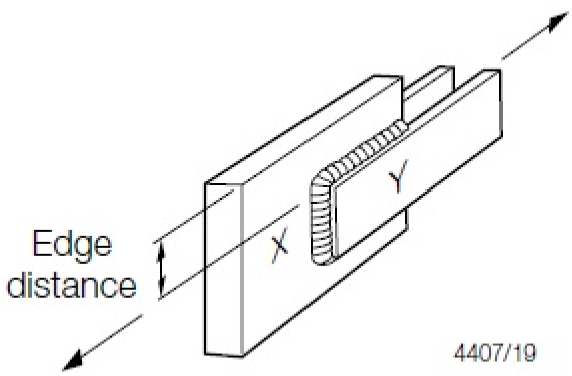
4.1 Parent metal (of the stressed member) adjacent to toes or ends of bevel-butt or fillet welded attachments, regardless of the orientation of the weld to the direction of applied stress and whether or not the welds are continuous round the attachment.	Butt welded joints should be made with an additional reinforcing fillet so as to provide a similar toe profile to that which would exist in a fillet welded joint.	
(a) With attachment length (parallel to the direction of the applied stress) ≤ 150 mm and with edge distance ≥ 10 mm.	F The decrease in fatigue strength with increasing attachment length is because more load is transferred into the longer gusset giving an increase in stress concentration.	
(b) With attachment length (parallel to the direction of the applied stress) > 150 mm and with edge distance ≤ 10 mm.	F2	
4.2 Parent metal (of the stressed member) at the toes or the ends of butt or fillet welded attachments on or within 10 mm of the edge or corners of a stressed member and regardless of the shape of the attachment.	G Note that the classification applies to all sizes of attachment. It would therefore include, for example, the junction of two flanges at right angles. In such situations a low fatigue classification can often be avoided by the use of a transition plate (*see also* joint Type 3.3).	

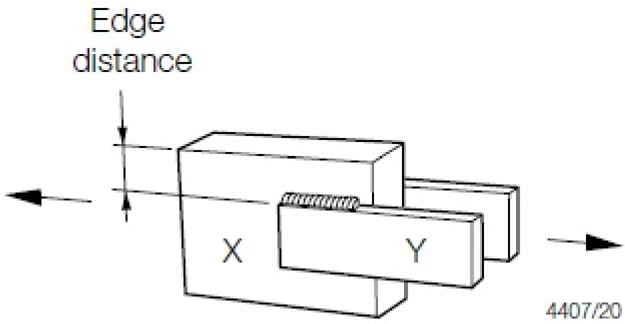
4.3 Parent metal (of the stressed member) at the toe of a butt weld connecting the stressed member to another member slotted through it.	Note that this classification does not apply to fillet welded joints (*see* joint Type 5.1b). However it does apply to loading in either direction (L or T in the sketch).	
(a) With the length of the slotted-through member, parallel to the direction of the applied stress, ≤150 mm and with edge distance ≥10 mm.	F	
(b) With the length of the slotted-through member, parallel to the direction of the applied stress, >150 mm and with edge distance ≥10 mm.	F2	
(c) With edge distance <10 mm.	G	

TYPE 5 LOAD-CARRYING FILLET AND T BUTT WELDS

Notes on potential modes of failure:

Failure in cruciform or T joints with full penetration welds will normally initiate at the weld toe, but in joints made with load-carrying fillet or partial penetration butt welds cracking may initiate either at the weld toe and propagate into the plate or at the weld root and propagate through the weld. In welds parallel to the direction of the applied stress, however, weld failure is uncommon, cracks normally initiate at the weld end and propagate into the plate perpendicular to the direction of applied stress. The stress concentration is increased, and the fatigue strength is therefore reduced, if the weld end is located on or adjacent to the edge of a stressed member rather than on its surface.

5.1 Joint description Parent metal adjacent to cruciform joints or T joints (member marked X in sketches).	Member Y can be regarded as one with a non-load-carrying weld (*see* joint Type 4.1). Note that in this instance the edge distance limitation applies.	
(a) Joint made with full penetration welds and with any undercutting at the corners of the member dressed out by local grinding.	F	
(b) Joint made with partial penetration or fillet welds with any undercutting at the corners of the member dressed out by local grinding.	F2 In this type of joint, failure is likely to occur in the weld throat unless the weld is made sufficiently large (*see* joint Type 5.4).	
5.2 Parent metal adjacent to the toe of load-carrying fillet welds which are essentially transverse to the direction of applied stress (member X in sketch).	The relevant stress in member X should be calculated on the assumption that its effective width is the same as the width of member Y.	
(a) Edge distance ≥10 mm.	F2 These classifications also apply to joints with longitudinal weld only.	
(b) Edge distance <10 mm.	G	

5.3 Parent metal at the ends of load-carrying fillet welds which are essentially parallel to the direction of applied stress, with the weld end on plate edge (member Y in sketch).	G	
5.4 Weld metal in load-carrying joints made with fillet or partial penetration welds, with the welds either transverse or parallel to the direction of applied stress (based on nominal shear stress on the minimum weld throat area).	W This includes joints in which a pulsating load may be carried in bearing, such as the connection of bearing stiffeners to flanges. In such examples the welds should be designed on the assumption that none of the load is carried in bearing.	

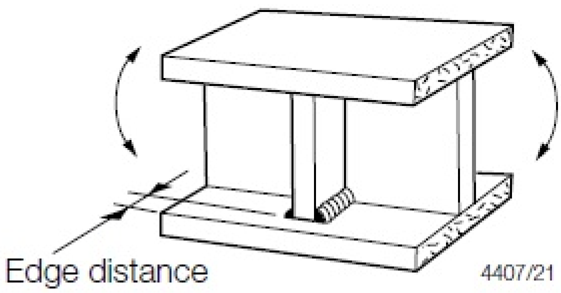
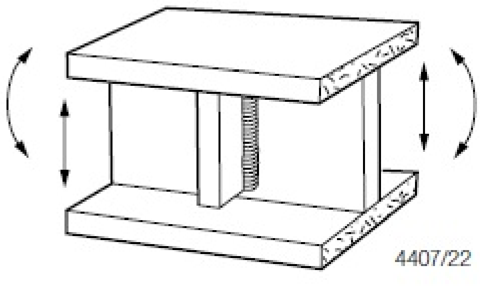
TYPE 6 DETAILS IN WELDED GIRDERS

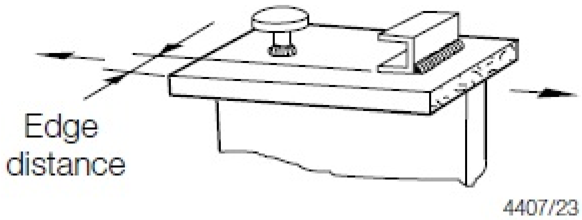
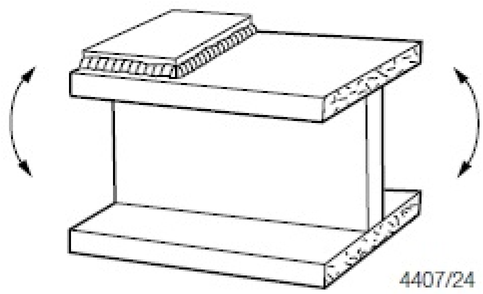
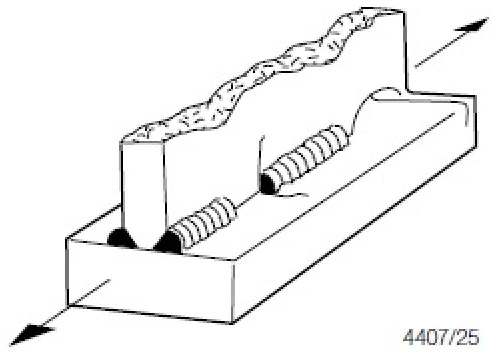
Notes on potential modes of failure:

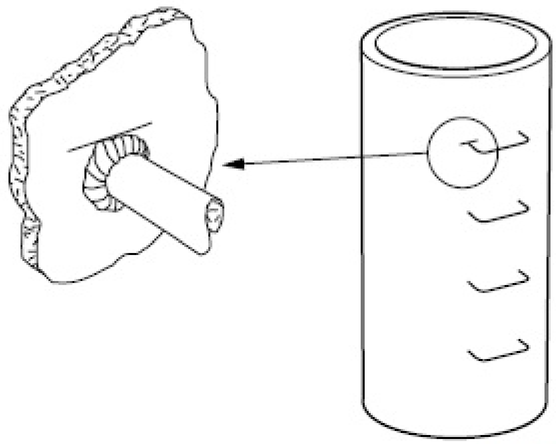
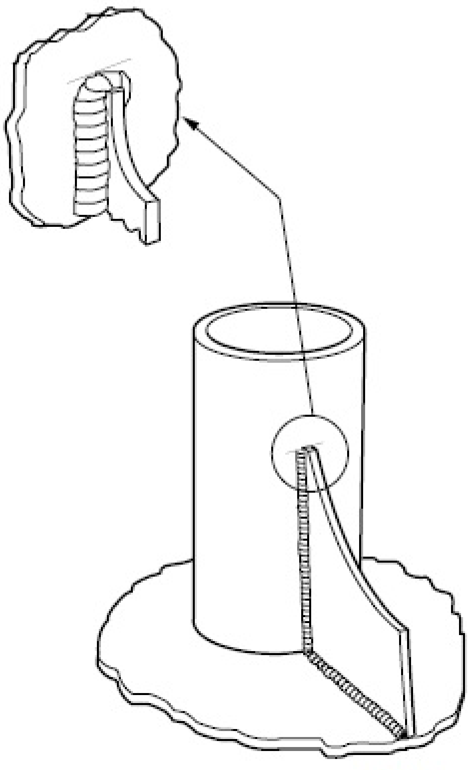
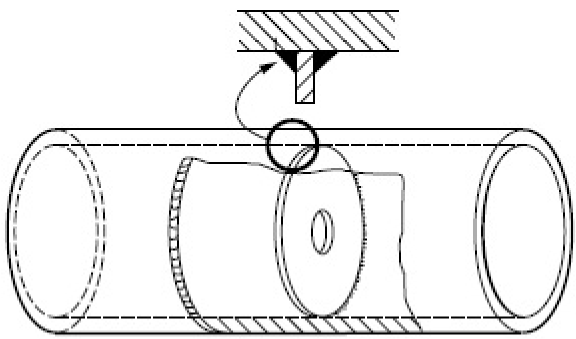
Fatigue cracks generally initiate at weld toes and are especially associated with local stress concentrations at weld ends, short lengths of return welds, and changes of direction. Concentrations are enhanced when these features occur at or near an edge of a part (*see* notes on joint Type 4).

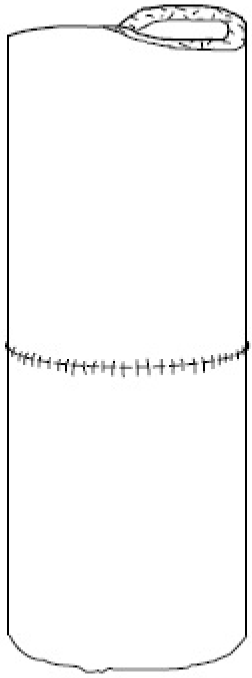
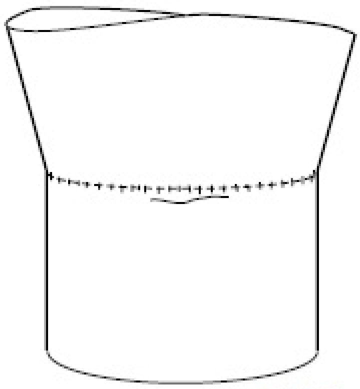
General comment:

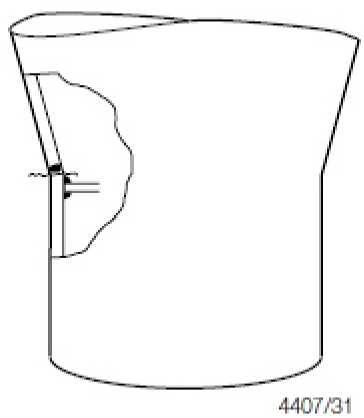
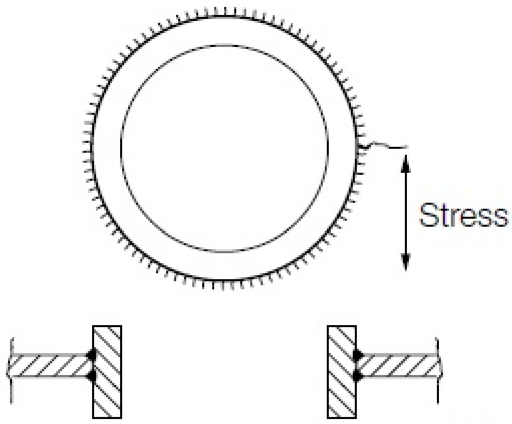
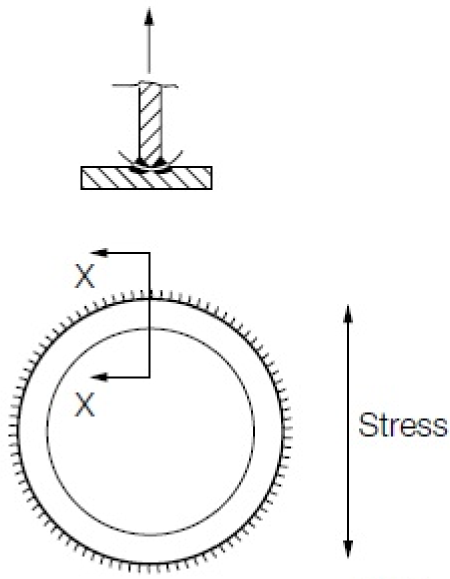
Most of the joints in this section are also shown, in a more general form in joint Type 4, they are included here for convenience as being the joints which occur most frequently in welded girders.

6.1 Parent metal at the toe of a weld connecting a stiffener, diaphragm, etc. to a girder flange.	Edge distance refers to distance from a free, i.e. unwelded edge. In this example, therefore, it is not relevant	
(a) Edge distance ≥10 mm (*see* joint Type 4.2).	F as far as the (welded) edge of the web plate is concerned. For reason for edge	
(b) Edge distance <10 mm.	G distance see note on joint Type 2.	
6.2 Parent metal at the end of a weld connecting a stiffener, diaphragm, etc. to a girder web in a region of combined bending and shear.	E This classification includes all attachments to girder webs.	

6.3 Parent metal adjacent to welded shear connectors. (a) Edge distance ≥10 mm. (b) Edge distance <10 mm (*see* Type 4.2).	 F G	
6.4 Parent metal at the end of a partial length welded cover plate, regardless of whether the plate has square or tapered ends and whether or not there are welds across the ends.	G This Class includes cover plates which are wider than the flange. However, such a detail is not recommended because it will almost inevitably result in undercutting of the flange edge where the transverse weld crosses it, as well as involving a longitudinal weld terminating on the flange edge and causing a high stress concentration.	
6.5 Parent metal adjacent to the ends of discontinuous welds, e.g. intermittent web/flange welds, tack welds unless subsequently buried in continuous runs. Ditto, adjacent to cope holes.	E This also includes tack welds which are not subsequently buried in a continuous weld. This may be particularly relevant in tack welded backing strips. Note that the existence of the cope hole is allowed for in the joint classification, F it should not be regarded as an additional stress concentration.	
TYPE 7 DETAILS RELATING TO TUBULAR MEMBERS		
7.1 Parent material adjacent to the toes of full penetration welded nodal joints.	T In this situation design should be based on the hot spot stress as defined in *Pt 4, Ch 5, 5 Fatigue design*(*see also* this Section for guidance on partial penetration welds).	

7.2 Parent metal at the toes of welds associated with small (≤150 mm in the direction parallel to the applied stress) attachments to the tubular member. As above, but with attachment length >150 mm.	F F2	 4407/26
7.3 Gusseted connections made with full penetration or fillet welds. (But note that full penetration welds are normally required).	F Note that the design stress must include any local bending stress adjacent to the weld end. W For failure in the weld throat of fillet welded joints.	 4407/27
7.4 Parent material at the toe of a weld attaching a diaphragm or stiffener to a tubular member.	F Stress should include the stress concentration factor due to overall shape of adjoining structure.	 4407/28

7.5 Parent material adjacent to the toes of circumferential butt welds between tubes.	In this type of joint the stress should include the stress concentration factor to allow for any thickness change and for fabrication tolerances.	 4407/29
(a) Welds made from both sides with the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.	C The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique should be selected with a view to ensuring the detection of such significant defects.	
(b) Weld made from both sides.	E	
(c) Weld made from one side on a permanent backing strip.	F	
(d) Weld made from one side without a backing strip provided that full penetration is achieved.	F2 Note that step changes in thickness are, in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining	
7.6 Parent material at the toes of circumferential butt welds between tubular and conical section.	F2 Class and stress should be those corresponding to the joint type as indicated in 7.5, but the stress must also include the stress concentration factor due to overall form of the joint. C E F	 4407/30

7.7 Parent material of the stressed member adjacent to the toes of bevel butt or fillet welded attachments in a region of stress concentration.	F Class depends on attachment length (*see* Type 4.1) but stress should include the stress concentration factor due to overall shape of adjoining structure. or F2	
7.8 Parent metal adjacent to, or weld metal in, welds around a penetration through the wall of a member (on a plane essentially perpendicular to the direction of stress). Note that full penetration welds are normally required in this situation.	D In this situation the relevant stress should include the stress concentration factor due to the overall geometry of the detail.	
7.9 Weld metal in partial penetration or fillet welded joints around a penetration through the wall of a member (on a plane essentially parallel to the direction of stress).	W The stress in the weld should include an appropriate stress concentration factor to allow for the overall joint geometry.	

■ *Section 4*
Stress concentration factors

4.1 General

4.1.1 In general, any discontinuity in a stressed structure results in a local increase in stress at the discontinuity. The ratio of the peak stress at the discontinuity to the nominal average stress that would prevail in the absence of the discontinuity is commonly referred to as the stress concentration factor (SCF). The peak stress (i.e. nominal stress x SCF) is normally used in conjunction with an appropriate S-N curve to derive the estimated fatigue life.

4.1.2 The design weld S-N curves are given in *Pt 4, Ch 12, 2 Fatigue design S-N curves* for the particular joint arrangements given in *Pt 4, Ch 12, 3 Fatigue joint classification*.

4.1.3 Stress concentration factors may be derived using a number of different methods, such as finite element techniques, closed form analytical formula or from model tests. For complex arrangements, a detailed finite element based analysis will most likely be required.

4.1.4 For semi-submersible units, experience has shown that the areas of minimum fatigue life are usually found at the joints, stiffener terminations, penetrations in primary bracings and also at their junctions with hull, columns and decks. For jack-up structures locations of minimum fatigue life are usually found on the lattice legs and support structure. Other structures subjected to significant cylic loading also require assessment.

4.1.5 Stress concentration factors for standard details may be determined from LR‘s technical report prepared for the UK HSE, *OTO 97-024 Geometric Stress Concentration Factors for Classified Details,* or an equivalent standard.

Stress concentration factors for tubular brace to chord connections may be determined from LR‘s technical report prepared for the UK HSE, *OTH 91-353 Stress Concentration Factors for Tubular Complex Joints*, or an equivalent standard.

4.1.6 Where finite element methods are used to determine local stress distributions for fatigue assessment, the geometric hot spot stress should account for the effect of structural discontinuities, excluding the presence of the weld. Misalignment of structural members should be accounted for where applicable.

4.1.7 Linear extrapolation over reference points at 0,5 and 1,5 x plate thickness away from the point of interest (normally the weld toe) may be made to determine the geometric hot spot stress.

4.1.8 In general, the geometric hot spot stress can be used in conjunction with the D class S-N curve given in *Pt 4, Ch 12, 2.2 Modifications to basic S-N curves 2.2.5*.

4.1.9 The maximum fabrication axial misalignment for fatigue prone locations would normally be limited to the smaller of 0,1 x t or 3 mm.

where

t = thickness of thinner plate

For this guidance, it may be assumed that the effects of these maximum fabrication misalignments are included within the S-N classification. Angular misalignment is to be mutually agreed between the designer and the fabricator, and is to be acceptable to LR.

Contents

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■ *Section 1* General

1.1 Application

1.1.1 General requirements for the design and construction of main and auxiliary machinery are given in *Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

1.1.2 Additional requirements with respect to unit types as indicated in this Chapter should also be complied with, as applicable.

1.2 Survey for classification

1.2.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power working conditions. Any defects, etc. are to be indicated as early as possible. On completion, the Surveyors will submit a report and if this is found to be satisfactory by the Classification Committee, a certificate will be granted and an appropriate notation will be assigned in accordance with *Pt 1, Ch 2 Classification Regulations*.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units, the Classification Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts, utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of *Pt 5, Ch 1, 6 Spare gear for machinery installations* are to be complied with.

1.4 Departures from the Rules

1.4.1 Where it is proposed to depart from the requirements of the Rules, the Classification Committee will be prepared to give consideration to the circumstances of any special case.

1.4.2 Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Classification Committee.

Section 2
Operating conditions

2.1 Inclination of unit

2.1.1 Main and essential auxiliary machinery is to operate satisfactorily under the conditions as shown in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1*, *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* or *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3*.

Table 1.2.1 Inclination of ship untis and other surface type units

<table>
<tr><th rowspan="3">Installations, components</th><th colspan="4">Angle of inclination, degrees, see Note 1</th></tr>
<tr><th colspan="2">Athwartships</th><th colspan="2">Fore-and-aft</th></tr>
<tr><th>Static</th><th>Dynamic</th><th>Static</th><th>Dynamic</th></tr>
<tr><td>Main and auxiliary machinery essential to the propulsion and safety of the unit</td><td>15</td><td>22,5</td><td>5
see Note 2</td><td>7,5</td></tr>
<tr><td>Emergency machinery and equipment fitted in accordance with Statutory Requirements</td><td>22,5</td><td>22,5</td><td>10</td><td>10</td></tr>
<tr><td colspan="5">NOTES
1. Athwartships and fore-and-aft inclinations may occur simultaneously.
2. Where the length of the unit exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:
$\frac{500}{L}$ degrees
where
L = length of unit, in metres, see Pt 4, Ch 1, 5 Definitions.</td></tr>
</table>

2.1.2 Any proposal to deviate from the angles given in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1*, *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* or *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* will be specially considered taking into account the type, size and service conditions of the unit.

2.1.3 The dynamic angles of inclination in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1*, *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* or *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* may be exceeded in certain circumstances, dependent upon type of unit and operation. The Builder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

Table 1.2.2 Inclination of column-stabilised units

<table>
<tr><th rowspan="2">Installations, components</th><th colspan="2">Angle of inclination in any direction, degrees</th></tr>
<tr><th>Static</th><th>Dynamic</th></tr>
<tr><td>Main and auxiliary machinery essential to the propulsion and safety of the unit</td><td>15</td><td>22,5</td></tr>
<tr><td>Ballast system, emergency machinery and equipment fitted in accordance with statutory requirements</td><td>22,5</td><td>22,5</td></tr>
</table>

Table 1.2.3 Inclination of self-elevating units

Installations, components	Angle of inclination in any direction, degrees	
	Static	Dynamic
Main and auxiliary machinery and equipment essential to the propulsion and safety of the unit	10	15
Emergency machinery and equipment fitted in accordance with statutory requirements	15	15

■ *Section 3* Machinery room arrangements

3.1 Accessibility

3.1.1 Accessibility for attendance and maintenance purposes is to be provided for machinery plants.

3.2 Machinery fastenings

3.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the unit's structure to the satisfaction of the Surveyor.

3.3 Resilient mountings

3.3.1 The dynamic angles of inclination in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1*, *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* or *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.3* may be exceeded in certain circumstances dependent upon unit type and operation. The Builder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

3.3.2 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

3.3.3 A plan showing the arrangement of the machinery together with documentary evidence of the foregoing is to be submitted.

3.4 Ventilation

3.4.1 All spaces including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions. *See also Pt 7, Ch 2 Hazardous Areas and Ventilation*.

3.4.2 Machinery spaces shall be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the operation of the machinery.

3.5 Fire protection

3.5.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

3.6 Means of escape

3.6.1 For means of escape from machinery spaces, *see Pt 7, Ch 3 Fire Safety*.

3.7 Communications

3.7.1 Two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled, *see also Pt 6, Ch 1, 2 Essential features for control, alarm and safety systems*.

3.7.2 One of these means is to indicate visually the order and response, both at the engine room control station and on the bridge.

3.7.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

3.8 Category A machinery spaces

3.8.1 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or fuel oil unit.

■ *Section 4* Trials

4.1 Inspection

4.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

4.2 Sea trials

4.2.1 For all types of installation, the sea trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

4.2.2 The trials are to include demonstrations of the following:

(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.
(b) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the unit to rest from maximum service speed. Results of the trials are to be recorded.
(c) In turbine installations, the ability to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects. This astern trial need only be of 15 minutes' duration, but may be extended to 30 minutes at the Surveyor's discretion.

4.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyors.

4.2.4 In geared installations, prior to full power sea trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the sea trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix where applicable. The contact is to be not less than that required by *Pt 5, Ch 5, 5.2 Meshing tests* as applicable.

4.2.5 The following information is to be available on board for the use of the Master and designated personnel:

- The results of trials to determine stopping times, unit headings and distance;
- For units having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative.
- For units having a single propulsor driven by multiple engines or electric motors, the results of trials to determine the ability to navigate and manoeuvre with the largest engine or electric motor inoperative.

4.2.6 Where the unit is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means is to be demonstrated and recorded as referred to in *Pt 5, Ch 1, 4.2 Sea trials 4.2.5*.

4.2.7 The stopping distance achieved when the unit is initially proceeding ahead with a speed of at least 90 per cent of the unit's speed corresponding to 85 per cent of the maximum rated propulsion power, should not exceed 15 unit lengths after the astern order has been given. However, if the displacement of the unit makes this criterion impracticable then in no case should the stopping distance exceed 20 unit lengths.

4.2.8 All trials are to be to the Surveyor's satisfaction.

■ *Section 5* Quality Assurance Scheme for Machinery

5.1 General

5.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

5.1.2 The Classification Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyors of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

5.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

5.1.4 Approval by another organisation will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

5.2 Requirements for approval

5.2.1 **Facilities**. The manufacturer is required to have adequate equipment and facilities for those operations appropriate to the level of design, development and manufacture being undertaken.

5.2.2 **Experience**. The manufacturer is to demonstrate that the firm has experience consistent with technology and complexity of the product type for which approval is sought and that the firm's products have been of a consistently high standard.

5.2.3 **Quality policy**. The manufacturer is to define management policies and objectives or quality and ensure that these policies and objectives are implemented and maintained throughout all phases of the work.

5.2.4 **Quality system documentation**. The manufacturer is to establish and maintain a documented quality system capable of ensuring that material or services conform to the specified requirements, including the requirements of this Section.

5.2.5 **Management representative**. The manufacturer is to appoint a management representative, preferably independent of other functions, who is to have defined authority and responsibilities for the implementation and maintenance of the quality system.

5.2.6 **Responsibility and authority**. The responsibilities and authorities of senior personnel within the quality system are to be clearly documented.

5.2.7 **Internal audit**. The manufacturer is to conduct internal audits to ensure continued adherence to the system. An audit programme is to be established with audit frequencies scheduled on the basis of the status and importance of the activity and adjusted on the basis of previous results.

5.2.8 **Management review**. The quality system established in accordance with the requirements of this Section is to be systematically reviewed at appropriate intervals by the manufacturer to ensure its continued effectiveness. Records of such management reviews are to be maintained and be made available to the Surveyors.

5.2.9 **Contract review**. The manufacturer is to establish and implement procedures for conducting a contract review prior to and after acceptance to ensure that:

(a) the requirements of the contract are adequately defined and documented;
(b) any requirements differing from those specified in the original enquiry/tender are resolved; and
(c) the manufacturer has the capability to meet and verify compliance to the specified requirements.

5.2.10 **Work instruction**. The manufacturer is to establish and maintain clear and complete written work instructions that prescribe the communication of specified requirements and the performance of work in design, development and manufacture which would be adversely affected by lack of such instructions.

5.2.11 **Documentation and change control**. The manufacturer is to establish and maintain control of all documentation that relates to the requirements of this scheme. This control is to ensure that:

(a) documents are reviewed and approved for adequacy by authorised personnel prior to use, are uniquely identified and include indication of approval and revision status;
(b) all changes to documentation are in writing and are processed in a manner that will ensure their availability at the appropriate location and preclude the use of nonapplicable documents;
(c) provision is made for the prompt removal of obsolete documentation from all points of issue or use; and
(d) documents are to be re-issued after a practical number of changes have been issued.

5.2.12 **Records**. The manufacturer is to develop and maintain a system for collection, use and storage of quality records. The period of retention of such records is to be established in writing and is to be subject to agreement by the Classification Committee.

5.2.13 **Design**. The manufacturer is to establish and maintain a design control system appropriate to the level of design being undertaken. Documented design procedures are to be established which:

(a) identify the design practices of the manufacturer's organisation including departmental instructions to ensure the orderly and controlled preparation of design and subsequent verification;
(b) make provision for the identification, documentation and appropriate approval of all design change and modifications;
(c) prescribe methods for resolving incomplete, ambiguous or conflicting requirements; and
(d) identify design inputs such as sources of data, preferred standard parts or materials and design information and provide procedures for their selection and review by the manufacturer for adequacy.

5.2.14 **Purchasing**. The manufacturer is to ensure that purchased material and services conform to specified requirements.

5.2.15 **Selection and approval of sub-contractors and suppliers**. The manufacturer is to establish and maintain records of acceptable suppliers and sub-contractors. The selection of such sources, and the type and extent of control exercised, are to be appropriate to the type of product or service and the suppliers' or sub-contractors' previously demonstrated capability and performance. Documented procedures for approval of new suppliers are to be established and records of vendor assessments (where carried out) are to be maintained and made available to the Surveyors upon request.

5.2.16 **Purchasing data**. Each purchasing document should contain a clear description of the material or service ordered, including, as applicable, the following:

(a) The type, class, grade, or other precise identification;
(b) The title or other positive identification and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant data.

5.2.17 **Verification of purchased material and services**. The manufacturer is to ensure that the Surveyors are afforded the right to verify at source or upon receipt that purchased material and services conform to specified requirements. Verification by the Surveyors shall not relieve the manufacturer of his responsibility to provide acceptable material nor is it to preclude subsequent rejection.

5.2.18 **Product identification**. The manufacturer is to establish and maintain a system for identification of the product to relevant drawings, specifications or other documents during all stages of production, delivery and installation.

5.2.19 **Manufacturing control**. The manufacturer is to ensure that those operations which directly affect quality are carried out under controlled conditions. These are to include the following:

(a) Written work instructions wherever the absence of such instructions could adversely affect compliance with specified requirements. These should define the method of monitoring and control of product characteristics.
(b) Established criteria for workmanship through written standards or representative samples.

5.2.20 **Special processes**. Those processes where effectiveness cannot be verified by subsequent inspection and test of the product are to be subjected to continuous monitoring in accordance with documented procedures, in addition to the requirements specified in *Pt 5, Ch 1, 6.2 Guidance for spare parts*.

5.2.21 **Receiving inspection**. The manufacturer is to ensure that all incoming material is not to be used or processed until it has been inspected or otherwise verified as conforming to specified requirements. In establishing the amount and nature of receiving inspection, consideration is to be given to the control exercised by the supplier and documented evidence of quality conformance supplied.

5.2.22 **In-process inspection**. The manufacturer is to:

(a) perform inspection during manufacture on all characteristics that cannot be inspected at a later stage;
(b) inspect, test and identify products in accordance with specified requirements;
(c) establish product conformance to specified requirements by use of process monitoring and control methods where appropriate;
(d) hold products until the required inspections and tests are completed and verified; and
(e) clearly identify non-conforming products to prevent unauthorised use, shipment, or mixing with conforming material.

5.2.23 **Final inspection**. The manufacturer is to perform all inspections and tests on the finished product necessary to complete the evidence of conformance to the specified requirements. The procedures for final inspection and test are to ensure that:

(a) all activities defined in the specification, quality plan or other documented procedure have been completed;
(b) all inspections and tests that should have been conducted at earlier stages have been completed and that the data is acceptable; and
(c) no product is to be dispatched until all the activities defined in the specifications, quality plan or other documented procedure have been completed, unless products have been released with the permission of the Surveyors.

5.2.24 **Inspection equipment**. The manufacturer is to be responsible for providing, controlling, calibrating and maintaining the inspection, measuring and test equipment necessary to demonstrate the conformance of material and services to the specified requirements or used as part of the manufacturing control system required by *Pt 5, Ch 1, 5.2 Requirements for approval 5.2.19* and *Pt 5, Ch 1, 5.2 Requirements for approval 5.2.20*.

5.2.25 **Inspection and test status**. The manufacturer is to establish and maintain a system for the identification of inspection status of all material, components and assemblies by suitable means which distinguish between conforming, non-conforming and uninspected items. The relevant inspection and test procedures and records are to identify the authority responsible for the release of conforming products.

5.2.26 **Control of non-conforming material**.

(a) The manufacturer is to establish and maintain procedures to ensure that material that does not conform to the specified requirements is controlled to prevent inadvertent use, mixing or shipment. Repair, rework or concessions on non-conforming material and re-inspection are to be in accordance with documented procedures.
(b) Records clearly identifying the material, the nature and extent of non-conformance and the disposition are to be maintained.

5.2.27 **Sampling procedures**. Where sampling techniques are used by the manufacturer to verify the acceptability of groups of products, the procedures adopted are to be in accordance with the specified requirements or are to be subject to agreement by the Surveyors.

5.2.28 **Corrective action**. The manufacturer is to establish and maintain documented procedures for the review of non-conformances and their disposition. These should provide for:

(a) monitoring of process and work operations and analysis of records to detect and eliminate potential causes of non-conforming material;
(b) continuing analysis of concessions granted and material scrapped or reworked to determine causes and the corrective action required;
(c) an analysis of customer complaints;
(d) the initiation of appropriate action with suppliers or subcontractors with regard to receipt of non-conforming material; and
(e) an assurance that corrective actions are effective.

5.2.29 **Purchaser supplied material**. The manufacturer is to establish and maintain documented procedures for the control of purchaser supplied material.

5.2.30 **Handling, storage, and delivery:**

(a) The manufacturer is to establish and maintain a system for the identification preservation, segregation and handling of all material from the time of receipt through the entire production process. The system is to include methods of handling that prevent abuse, misuse, damage or deterioration.
(b) Secure storage areas or rooms are to be provided to isolate and protect material pending use. To detect deterioration at an early stage, the condition of material is to be periodically assessed.
(c) The manufacturer is to arrange for the protection of the quality of his product during transit. The manufacturer is to ensure, in so far as it is practicable, the safe arrival and ready identification of the product at destination.

5.2.31 **Training**. The manufacturer is to follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. Appropriate records are to be maintained to demonstrate that all personnel performing process control, special processes inspection and test or quality system maintenance activities have appropriate experience or training.

5.3 Arrangements for acceptance and certification of purchased material

5.3.1 The manufacturer is to establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant. The manufacturer's system for control of such purchased material may be based on one of the following alternatives, subject to the approval of LR:

(a) Product certification by LR's Surveyors at the supplier's works in accordance with the requirements of the Rules for Materials.
(b) Agreed Inspection Procedures at the manufacturer's plant combined with documentary evidence of vendor assessments, vendor rating records and annual surveillance visits to the suppliers.
(c) Recognition of quality agreements between the manufacturer and his suppliers which are to provide for initial vendor assessments and regular surveillance visits (a minimum of four per year). The quality agreement must identify the individual in the supplier's plant who is charged with the responsibility for release of materials or components and the procedures to be adopted.

5.3.2 The alternatives proposed in *Pt 5, Ch 1, 5.3 Arrangements for acceptance and certification of purchased material 5.3.1* and *Pt 5, Ch 1, 5.3 Arrangements for acceptance and certification of purchased material 5.3.1* are not acceptable to LR for the following items:

(a) Engine components for which testing is a Rule requirement; and
   (i) the cylinder bore is equal to or exceeds 300 mm; or
   (ii) which are made by open forging techniques.
(b) Cast crankshafts where the journal diameter exceeds 85 mm.

5.3.3 Where the manufacturer's system for control of purchased material is based upon *Pt 6, Ch 1, 3 Ergonomics of control stations*, the Surveyors shall also make surveillance visits to the supplier's works at the minimum specified intervals. The manufacturer is also to make available to the Surveyors documentary evidence of the operation of quality agreements or Agreed Inspection Procedures where applicable.

5.4 Information required for approval

5.4.1 Manufacturers applying for approval under this scheme are to submit the following information:

(a) A description of the products for which certification is required including, where applicable, model or type number.
(b) Applicable plans and details of material used.
(c) An outline description of all important manufacturing plant and equipment.
(d) A summary of equipment used for measuring and testing during manufacture and completion.
(e) The Quality Manual.
(f) A typical production flow chart and quality plan covering all stages from ordering of materials to delivery of the finished product.
(g) The system used for the identification of raw materials, semi-finished and finished products.
(h) The number and qualifications of all staff engaged in testing, inspection and quality control duties.
(i) A list of suppliers of components and manufacturers, proposed procedures to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant.

5.5 Assessment of works

5.5.1 After receipt and appraisal of the information requested in *Pt 5, Ch 1, 5.4 Information required for approval*, an inspection of the works is to be carried out by the Surveyors to examine in detail all aspects of production, and in particular the arrangements for quality control.

5.5.2 The Surveyors will not specify in detail acceptable quality control procedures, but will consider the arrangements proposed by the works in relation to the manufacturing processes and products.

5.5.3 In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures are to be revised in order to be acceptable to LR.

5.5.4 Gauging, measuring and testing devices are to be made available to the Surveyors, and where appropriate, personnel for the operation of such devices.

5.6 Approval of works

5.6.1 If the initial assessment of the works confirms that the manufacturing and quality control procedures are satisfactory, the Classification Committee will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given. This Certificate will be valid for three years with renewal subject to satisfactory performance and to a satisfactory triennial reassessment.

5.6.2 An extension of approval in respect of product type may be given at the discretion of the Classification Committee without any additional survey of the works.

5.6.3 LR will publish a list of manufacturers whose works have been approved.

5.7 Maintenance of approval

5.7.1 The arrangements authorised at each works are to be kept under review by the Surveyors in order to ensure that the approved procedures for manufacture and quality control are being maintained in a satisfactory manner. This is to be carried out by:

(a) regular and systematic surveillance;
(b) intermediate audits at intervals of six months;
(c) triennial reassessment of the entire quality system.

5.7.2 For the purpose of regular and systematic surveillance, the Surveyors are to visit the works at intervals determined by the type of product and the rate of production. The Surveyors are to advise a senior member of the quality control department in regard to any matter with which they are not satisfied.

5.7.3 When minor deficiencies in the approved procedures are disclosed during the systematic surveillance the Surveyors may, at their discretion, apply more intensive supervision, including the direct inspection of products.

5.7.4 Any noteworthy departures from the approved plans of specifications are to be reported to the Surveyors and their written approval obtained prior to despatch of the item.

5.7.5 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained.

5.7.6 In addition to the regular visits by the Surveyors, an intermediate audit is to be carried out every six months. This will normally be carried out by Surveyors other than those regularly in attendance at the works. This audit is to consist of an examination of part of the manufacturer's quality system. An audit plan will be established indicating those areas of the quality system which will be examined during every intermediate audit and the frequency of examination of other areas such that all areas are subject to audit before reassessment is due.

5.7.7 The manufacturer's entire quality system is to be subject to reassessment at three-yearly intervals. This is to be conducted by Surveyors nominated by LR.

5.8 Suspension or withdrawal of approval

5.8.1 When the Surveyors have drawn attention to significant faults or deficiencies in the manufacturing or quality control procedures and these have not been rectified, approval of the works will be suspended. In these circumstances, the manufacturer will be notified in writing of the Classification Committee's reasons for the suspension of approval.

5.8.2 When approval has been suspended and the manufacturer does not effect corrective measures within a reasonable time, the Classification Committee will withdraw the Quality Assurance Approval Certificate.

5.9 Identification of products

5.9.1 In addition to the normal marking by the manufacturer, all certified products are to be hard stamped on a principal component with a suitable identification, LR's brand and the number of the approved works.

5.9.2 After issue of the Quality Assurance Approval Certificate, products may be dispatched with certificates signed on behalf of the manufacturer by an authorised senior member of the quality control department or by an authorised deputy. These certificates are to be countersigned by the Surveyor to certify that the approved arrangements are being kept under review by regular and systematic auditing of the manufacturer's quality system.

5.9.3 The following declarations are to be included on each certificate:

(a) 'This is to certify that the items described above have been constructed and tested with satisfactory results in accordance with the Rules of Lloyd's Register. Signed... Manager of QC Department.'

(b) 'This certificate is issued by the manufacturer in accordance with the arrangements authorised by Lloyd's Register in Quality Assurance Approval Certificate No. QA.M.................................. I certify that these arrangements are being kept under review by regular and systematic auditing of the approved manufacturing and quality control procedures. Signed.. Surveyor to Lloyd's Register'.

5.9.4 In the event of noteworthy departures from the approved plan or specification being accepted, a standard 'Concession' form is to be completed and signed by the following authorised persons: the design Manager, the Quality Control Manager or their deputies. In all cases, where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

■ *Section 6*
Spare gear for machinery installations

6.1 Application

6.1.1 Adequate spare parts for the propelling and essential auxiliary machinery, together with the necessary tools for maintenance and repair, are to be readily available for use.

6.1.2 The spare parts to be supplied and their location is to be the responsibility of the Owner, but they must take into account the design and arrangement of the machinery and the intended service and operation of the unit. Account must also be taken of the recommendations of the manufacturers and any applicable requirement of the relevant Administration.

6.2 Guidance for spare parts

6.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct.

Section 1
General

1.1 Application

1.1.1 Requirements for engines are given in *Pt 5, Ch 2 Reciprocating Internal Combustion Engines* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for steam turbines are given in *Pt 5, Ch 3 Steam Turbines* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for gas turbines are given in *Pt 5, Ch 4 Gas Turbines* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for machinery gearing are given in *Pt 5, Ch 5 Gearing* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for main propulsion shafting are given in *Pt 5, Ch 6 Main Propulsion Shafting* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for propellers are given in *Pt 5, Ch 7 Propellers* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for shaft vibration and alignment are given in *Pt 5, Ch 8 Shaft Vibration and Alignment* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for podded propulsion units are given in *Pt 5, Ch 9 Podded Propulsion Units* of the *Rules and Regulations for the Classification of Ships, July 2016*, which should be complied with.

1.1.2 Where Thruster Condition Monitoring (ThCM) Descriptive Note has been requested, refer to ShipRight Machinery Planned Maintenance and Condition Monitoring, Section 6.

Section 1
General

1.1 Application

1.1.1 Requirements for steam raising plant and associated pressure vessels are given in *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels*, are given in *Pt 5, Ch 11 Other Pressure Vessels* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

1.1.2 For the construction and design of pressure vessels and plate heat exchangers for liquefied gas applications, *see Pt 11 PRODUCTION, STORAGE AND OFFLOADING OF LIQUEFIED GASES IN BULK*.

Section 1
General

1.1 Application

1.1.1 Requirements for piping design are given in *Pt 5, Ch 12 Piping Design Requirements* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

■ *Section 1* General

1.1 Application

1.1.1 Requirements for bilge and ballast piping systems are given in *Pt 5, Ch 13 Ship Piping Systems* of the *Rules and Regulations for the Classification of Ships, July 2016*, which should be complied with except where otherwise stated.

1.1.2 Additional requirements with respect to unit types as indicated in this Chapter should also be complied with, as applicable.

■ *Section 2* Construction and installation

2.1 Valves and fittings on the side of the unit (other than those on scuppers and sanitary discharges)

2.1.1 Inlet and discharge valves in compartments situated below the assigned loadline and located in normally unattended spaces are to be provided with remote control which is capable of operating when submerged. *See also Pt 5, Ch 13, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)* of the Rules for Ships.

2.1.2 For column-stabilised units all sea inlet and overboard discharge valves are to be provided with remote control.

2.1.3 Where remote operation is provided by power-activated valves for sea inlets and discharges for supply to fire pumps, power supply failure of the control system is not to result in the closing of open valves or the opening of closed valves.

2.1.4 Consideration will be given to accepting bilge alarms in lieu of remote operation for surface type and self-elevating units. *See also* Section 10 and *Pt 6, Ch 1 Control Engineering Systems*.

■ *Section 3* Drainage of compartments, other than machinery spaces for column-stabilised units

3.1 General

3.1.1 Bilge systems are to be capable of operating satisfactorily under the conditions as shown in Table 1.1.2 in Chapter 1.

3.1.2 Provision is to be made for detection and drainage of leakage within main bracings that are sealed against the ingress of sea-water when submerged in operating conditions.

3.1.3 For the members mentioned in *Pt 5, Ch 13, 3.1 General 3.1.2* and other regions of the unit, where numerous small compartments are provided, arrangements are to be made for venting, draining and sounding, except where flooding of one or more compartments will not materially affect the stability criteria. Nevertheless, provision is to be made for the detection of leakage in each compartment. In all cases, fault condition alarms are to be provided at the central control station.

3.1.4 Special consideration is to be given to the design and workmanship of fittings and penetrations in the bracings. *See Pt 4, Ch 8, 5 Structural details*.

■ *Section 4*
Additional bilge drainage requirements for column-stabilised units and self-elevating units

4.1 Location of bilge pumps and bilge main

4.1.1 In accommodation units, the power bilge pumps required by *Pt 5, Ch 13, 6.1 Number of pumps 6.1.5* of the Rules for Ships are to be placed, if practicable, in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible. *See also Pt 5, Ch 13, 6 Pumps on bilge service and their connections* of the Rules for Ships.

4.1.2 In accommodation units of 91,5 m or more in length, or having a bilge pump numeral of 30 or more, *see Pt 5, Ch 13, 6.1 Number of pumps 6.1.5* of the Rules for Ships, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the unit may be flooded at sea. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck; or
- the pumps and their sources of power are so disposed throughout the length of the unit that, under any conditions of flooding which the unit is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

4.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the unit than $B/5$, measured at right angles to the centreline at the level of the deepest subdivision load line, where B is the breadth of the unit.

4.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $B/5$ line, a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the $B/5$ line.

4.2 Prevention of communication between compartments in the event of damage

4.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the unit than $B/5$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

4.3 Arrangement and control of bilge valves

4.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from the bulkhead deck. Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

4.3.2 All valves and cocks in *Pt 5, Ch 13, 4.3 Arrangement and control of bilge valves 4.3.1* which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

4.4 Cross-flooding arrangements

4.4.1 Where divided deep tanks or side tanks are provided with cross-flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross-flooding fittings are provided, they are to be operable from above the bulkhead deck. Additional bilge drainage requirements for column-stabilised units and self-elevating units are given in *Pt 5, Ch 13, 4.5 General* to *Pt 5, Ch 13, 4.7 Self-elevating units*.

4.5 General

4.5.1 The bilge system is to be capable of operating satisfactorily under the conditions specified in Table 1.1.2 or 1.1.3 in Chapter 1.

4.5.2 Dry compartments below the lowest continuous deck on self-elevating units, and below the main deck on column-stabilised units, containing essential equipment for the operation and safety of the unit, or providing essential buoyancy, are to have a permanently installed bilge pumping system.

4.5.3 Where the open drain pipe is carried through a watertight bulkhead or deck, it is to be fitted with an easily accessible self-closing valve at the bulkhead or deck, or a valve capable of being closed from above the damage waterline.

4.5.4 A mimic panel showing all the compartments and arrangements of the bilge and drainage systems is to be suitably positioned at the central control station.

4.6 Column-stabilised units

4.6.1 The internal diameter of branch suctions from each compartment is not to be less than stipulated by the following formula, rounded to the nearest 5 mm size:

$$d = 2,15\sqrt{A} + 25 \text{ mm}$$

where

A is wetted surface m^2 of the compartment, excluding stiffening members when the compartment is half filled with water.

4.6.2 The internal diameter of any bilge line is not to be less than 50 mm.

4.6.3 The cross sectional area of the main bilge line is not to be less than the sum of the cross sectional areas of the two largest branch bilge lines.

4.6.4 Each bilge pump is to be capable of giving a speed of water through the bilge main of not less than 2 m/s under ordinary working conditions.

4.6.5 At least one of the pumps referred to in *Pt 5, Ch 13, 6 Pumps on bilge service and their connections* of the Rules for Ships is to be arranged solely for bilge pumping duties. This pump and the pump-room bilge suction valves are to be capable of both remote and local operation.

4.6.6 Bilge drainage systems as defined above are not to directly connect compartments of different hazard classifications.

4.6.7 All distribution boxes and manually operated valves in connection with the bilge pumping arrangements are to be in positions which are accessible under normal circumstances. Where such valves are located in normally unmanned spaces below the assigned load line which are not provided with high bilge water level alarms, they are to be operable from outside the space. A means to indicate whether a valve is open or closed is to be provided at each location from which the valve can be controlled. The indicator is to rely on movement of the valve spindle.

4.6.8 Propulsion rooms and pump-rooms in lower hulls, which are normally unattended, are to be provided with two independent systems for bilge water high level detection, providing an audible and visual alarm at the central control station.

4.6.9 Chain lockers which, if flooded, could substantially affect the unit's stability are to be provided with a remote means to detect flooding, a permanently installed means of dewatering and remote indication provided at the central control station. The dewatering system is to be independent of the main bilge system and the pumps are to have adequate reserve capacity to keep the chain locker empty in any damage condition. The minimum discharge capacity of the pumps is not to be less than the flow rate calculated using the internal diameter of the chain pipe when subjected to a head of water measured from the top of the chain pipe to the 4 m waterline defined in *Pt 4, Ch 7, 4.7 Weathertight integrity related to stability 4.7.2*

4.7 Self-elevating units

4.7.1 The bilge system is to be arranged so that essential compartments such as machinery and pump-rooms can be emptied even when the unit is in the flooded condition. The control and position indication system for the bilge valves is to be suitable for operation if the equipment should become submerged.

4.7.2 At least one of the pumps referred to in *Pt 5, Ch 13, 6 Pumps on bilge service and their connections* of the Rules for Ships is to be arranged solely for bilge pumping duties.

4.7.3 Chain lockers, if fitted, may be emptied by means of portable pumps or permanently installed pumps or ejectors. Where the utilisation of portable pumps is intended, two units are to be carried on board.

■ *Section 5*
Ballast system

5.1 General requirements

5.1.1 Units are to be provided with an efficient pumping system capable of ballasting and de-ballasting any ballast tank under normal operating and transit conditions. The system is to be arranged to prevent inadvertent transfer of ballast from one tank or hull to another.

5.1.2 The ballast system is to be arranged so that it will remain operable, and tanks can be effectively de-ballasted through at least one suction, up to angles of inclination as specified in Tables 1.1.1, 1.1.2 and 1.1.3 in Chapter 1, as applicable.

5.1.3 The system is to be designed so that a single failure or mal-operation of any item of equipment or component will not lead to uncontrolled liquid movement. Pumps, piping and control systems should not be situated within the defined damage penetration zones, *see Pt 5, Ch 13, 1.2 Prevention of progressive flooding in damage condition* of the Rules for Ships.

5.2 Pumps

5.2.1 At least two independently driven ballast pumps are to be provided and arranged so that the system will remain operable in the event of failure of any one pump. Consideration should be given to locating the pumps in separate compartments where, in the event of flooding, fire or other damage in a particular compartment, an alternative pump in an unaffected compartment will be available. Such pumps need not be dedicated ballast pumps, but must be readily available for use on the ballast system at all times.

5.2.2 The capacity of each ballast pump is to be sufficient to provide safe handling and operation of the unit.

5.2.3 Ballast pumps should be self-priming unless it can be demonstrated that this would be unnecessary for the intended application. Pumps of the centrifugal type are to be self-priming by means of an automatic priming system.

5.3 Piping and valves

5.3.1 Ballast pipes are to be of steel or other approved material. Special consideration should be given to the design of pipes passing through tanks, particularly with regard to the effects of corrosion.

5.3.2 All valves are to be clearly marked to identify their function. Positive indication (open/closed) is to be provided at the valve, and at all positions from which the valve can be controlled. The indicators are to rely on the movement of the valve spindle.

5.3.3 The valves in the ballast system are to be self-closing by mechanical means or be power-operated by either a stored energy system provided with no fewer than two power units, or by an electrical supply system. Consideration should also be given to the need for equipment to operate when submerged.

5.3.4 The closing speed of power-operated valves should be limited where necessary, to prevent excessive pressure surges.

5.3.5 Valves which fail to set position are to be provided with an independent secondary means of closure from a readily accessible position above the damage waterplane. Power failure to sea-water inlet and discharge valves for systems such as cooling for essential machinery or for supply to fire pumps should not result in closing of open valves or in opening of closed valves. Such systems, which require the inlet/discharge valve to fail to a set position, are not to share a common inlet/discharge with systems in which the valves fail closed.

5.3.6 All sea inlet and discharge valves which are submerged at maximum operating draught and are located in normally unattended spaces are to be remotely controlled from a manned control station. Such valves are to fail automatically to the closed position on loss of control or actuating power unless overriding considerations require a valve to fail to set position.

5.4 Control of pumps and valves

5.4.1 All ballast pumps and power-operated valves are to be fitted with independent local control, which may be manual control, in addition to the remote control from the central control station. The independent local control of each ballast pump and of its associated tank valves should be in the same location. Such local controls are to be readily accessible and, where practicable, their access routes should not be situated within the defined damage penetration zones, *see Pt 5, Ch 13, 1.2 Prevention of progressive flooding in damage condition* of the Rules for Ships. A diagram of the representative part of the ballast system is to be permanently displayed at each location.

5.4.2 The control systems are to function independently of the indicating systems, or have sufficient redundancy, such that failure of one system does not jeopardise the operation of the other systems.

5.4.3 Valves which have failed closed should, on restoration of power, remain closed until the operator assumes control of the reactivated system.

5.4.4 For requirements relating to control and supervision of unattended ballast pumps located in dangerous or hazardous spaces, *see Pt 7, Ch 2, 5.1 General 5.1.8*.

5.5 Column-stabilised units

5.5.1 The general requirements of *Pt 5, Ch 13, 5.1 General requirements* to *Pt 5, Ch 13, 5.4 Control of pumps and valves* are to be complied with unless otherwise specified in this Section.

5.5.2 The ballast system is to have the capability to bring the unit, while in an intact condition, from the maximum normal operating draught to a severe storm draught or a decrease in draught of 4,6 m, whichever distance is greater, within three hours.

5.5.3 In the damage condition, *see Pt 4, Ch 7*, the system is to have the capability of restoring the unit to a level trim and safe draught condition without taking additional ballast and with any one pump inoperable.

5.5.4 The ballast system sea-water inlets and discharges should be separate from those of other systems.

5.5.5 Ballast system manifolds are to be arranged such that a specially defined operational procedure must be carried out when ballast is transferred from one end or side of the unit to the other.

■ *Section 6*
Air, overflow and sounding pipes for columnstabilised units

6.1 Size of air pipes

6.1.1 For each ballast tank, air pipes of sufficient size and number are to be provided to permit the efficient operation of the ballast pumping system under conditions referred to in *Pt 5, Ch 13, 5.1 General requirements*. To allow de-ballasting of tanks intended to be used to bring the unit back to normal draught, and to ensure no inclination after damage, air pipe openings are to be above the worst damage waterline, and positioned outside the defined damage penetration zones, *see Pt 4, Ch 7, 4 Watertight integrity*.

6.2 Sounding arrangements

6.2.1 Ballast tanks are to be provided with sounding pipes or other suitable sounding devices which are separate and additional to any remote sounding systems. The soundings are to be taken as near to the suction pipes as practicable. Where remote sounding systems are fitted, the indications are to be located in the central control station.

■ *Section 1* General

1.1 Application

1.1.1 Requirements for machinery piping systems are given in *Pt 5, Ch 14 Machinery Piping Systems* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

1.1.2 Additional requirements in this Chapter should also be complied with, as applicable.

■ *Section 2* Helicopter refuelling facilities

2.1 Fuel storage

2.1.1 Storage tanks and skids are to be located in a designated area as remote as practicable from machinery and accommodation spaces, escape routes and embarkation stations and are to be suitably isolated from areas where there are sources of ignition.

2.1.2 The storage and handling area is to be permanently marked. Instructions for filling fuel are to be posted in the vicinity of the filling area.

2.1.3 The tanks are to be protected from helicopter crashes, mechanical damage, solar and flare radiation and high temperatures as a result of a fire occurring in an adjacent area.

2.1.4 Tanks are to be of approved metallic construction and special attention is to be given to the inspection procedures, mounting and securing arrangements and electrical bonding of the tank and fuel transfer system. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and are to comply with the relevant Codes for the transportation of dangerous goods in ships.

2.1.5 Tank ventilation pipes are to be fitted with an approved type of vent head with pressure-vacuum valve and flame arrester. The vent outlet is to be located in a safe position away from accommodation spaces and ventilation intakes.

2.1.6 The fuel storage area is to be provided with a collecting tray of suitable capacity for containing leakage from the tanks and pumping units, and for draining any such leakage to a tank or container located in a safe area. For tanks forming an integral part of the unit's structure, cofferdams are to be provided as necessary to contain leakage and prevent contamination of the fuel.

2.2 Fuel pumping and filling

2.2.1 The tank outlet valve is to be mounted directly onto the tank and shall be capable of being closed from a remote location in the event of fire. Ball valves are to be stainless steel, anti-static, fire-tested type.

2.2.2 The pumping unit is to be connected to only one tank at a time. Pipes between the tanks and the pumping unit are to be of stainless steel or equivalent material, or flexible hoses of an approved type, fire-tested to an acceptable National Standard. Such pipes or hoses are to be protected from mechanical damage and be as short as possible. Where a flexible hose is used to connect the pumping unit to a tank, the hose connection is to be of the quick-disconnect, self-closing type.

2.2.3 Pumping units are to be capable of being controlled from the refuelling station.

2.2.4 Pumping units are to incorporate a device to prevent over-pressurisation of the filling hose.

2.2.5 Arrangements for fuel metering and sampling are to be provided.

■ *Section 3*
Requirements for boilers and heaters

3.1 Scope

3.1.1 In the context, the term'boilers' also includes steam boilers, Glycol/Amine/Selexol, etc. reboilers and thermal oil heaters, which are fired units.

3.2 General

3.2.1 For all fired boilers, the pre-purge is to be sufficient to give at least 5 air changes in the furnace and/or at least 2,5 complete air changes of the furnace and uptakes, whichever is greater.

3.2.2 Combustion air is to be taken from a safe area.

3.2.3 Gas-fired boilers are to be fitted with fuel oil pilot igniter system. A fuel gas system or electric spark ignition for the main burner are not acceptable systems.

3.2.4 Gas detectors are to be fitted in the combustion air intake trunking, that will shut down the boiler and alarm at a manned station.

3.2.5 Boilers are to be located in areas designated 'safe areas'. If the boiler cannot be fitted in an area designated 'safe area' then it must be fitted with the following:

(a) The furnace must be a closed front type.
(b) The combustion air must be ducted from an area designated a 'safe area' and fitted with a flame arrestor.
(c) The combustion air intake is to be fitted with a gas detector which will alarm and shut down the flame on gas detection.
(d) A gas detector is to be fitted near to the boiler in the compartment in which the boiler is located.
(e) The maximum surface temperatures as given in the Rules are to be complied with.

3.2.6 *Pt 5, Ch 14, 3.2 General 3.2.10* shows a typical arrangement for a boiler room.

3.2.7 For boilers that use fuel gas, *see Pt 5, Ch 16 Gas and Crude Oil Burning Systems* as applicable.

3.2.8 For boilers located in a safe area, combustion air may be taken from the boiler compartment.

3.2.9 Boiler compartment ventilation is to be a minimum of 12 air changes per hour.

3.2.10 All boilers are to be fitted with a method of leak detection depending upon the fluid contained in the boiler. Adequate leak collection and drainage is to be provided.

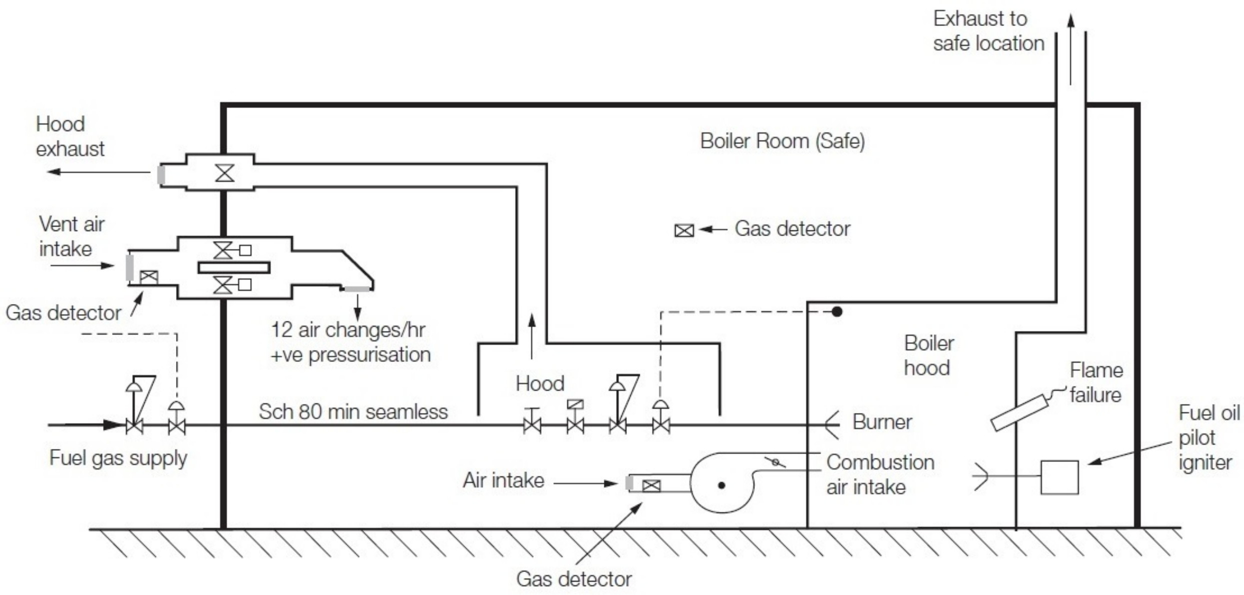


Figure 14.3.1 Diagram showing the typical arrangements for a boiler room

3.2.11 **Thermal oil boilers/heaters**

3.2.12 The requirements for thermal oil boilers and heaters are given in *Pt 5, Ch 15, 6.5 Temperature indication* of the Rules for Ships.

Section 1
General

1.1 Application

1.1.1 Requirements for piping systems for oil storage tanks are given in *Pt 5, Ch 15 Piping Systems for Oil Tankers* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General requirements

1.1 General

1.1.1 Gas from the unit's process plant may be utilised as fuel in gas turbines/engines and auxiliary boilers/fired heaters, and crude oil/slops may be used in auxiliary boilers/fired heaters, provided the requirements of this Chapter are complied with. Diagrammatic plans showing ventilation arrangements, piping system layout and safety devices should be submitted for approval in each case.

1.1.2 Boilers, turbines, etc. which are arranged for burning gas or crude oil/slops are to be located within designated non-hazardous areas such as a boiler or turbine room or enclosure.

1.1.3 The design and construction of turbines, boilers, burners, etc. is to be suitable for operation on gas or crude oil as appropriate, effectively maintaining stable and complete combustion under all operating conditions.

1.1.4 The design of gas-burning internal combustion reciprocating engines and turbines will be specially considered in each case. For special requirements relating to boilers/fired heaters burning gas or crude oil/slops, *see Pt 5, Ch 16, 1.6 Special requirements for boilers/fired heaters*.

1.1.5 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Fuel gas supply arrangements

1.2.1 Gas which is taken directly from the process plant is to be treated before distribution. The system should include suitable treatment equipment to provide well-mixed, liquid-free gas at constant pressure.

1.2.2 The gas treatment system is to be located within a designated hazardous area. This area is to be separated from the boiler room or machinery space by a gas-tight bulkhead.

1.2.3 Liquid drains from the treatment equipment are to be led to a closed drain recovery system. Gas lines downstream of the treatment equipment should be heat traced or insulated as necessary to prevent condensation and hydrate formation.

1.2.4 A separate and independent gas supply line is to be provided for each gas burning unit and each line is to be provided with a fuel gas master valve arranged to close automatically if gas leakage is detected, or on loss of the required ventilation from the pipe duct or casing, or loss of pressurisation of the double-walled piping, *see Pt 5, Ch 16, 1.4 Piping requirements 1.4.2*.

1.2.5 The fuel gas master valves and pressure regulators/reducing valves are to be located external to the boiler room or machinery space.

1.2.6 The gas supply line to each gas burning unit is to be fitted with a double block-and-bleed system utilising three automatic valves comprising two valves in series enabling the gas supply to be shut off and vented via a third valve to atmosphere at a safe location. These valves are to be arranged so that failure of the required ventilation, flame failure at the burners, abnormal gas supply pressure or loss of the valve actuating medium will cause the two valves in series to close and the vent valve between them to open. The valves are to be arranged for manual reset.

1.2.7 All master valves and block-and-bleed valves are to be arranged for remote operation from a location outside the boiler room or machinery space, and for local operation from the boiler or turbine control console.

1.2.8 The operation of the master valves or block-andbleed valves is to activate an alarm in the machinery space and in the central control room.

1.2.9 For long runs of high pressure gas piping, consideration should be given to the fitting of a self-closing 'safety block valve' between adjoining all-welded sections of piping, which would automatically isolate the gas supply in cases of pipe fracture.

1.2.10 Provision is to be made for gas-freeing and inerting that portion of the fuel gas piping system located in the boiler room or machinery space.

1.2.11 Suitable arrangements are to be made for change over between gas and oil fuel so that change over can be accomplished quickly and easily.

1.3 Crude oil supply arrangements

1.3.1 Crude oil or slops may be taken directly from the unit's storage tanks, or from other suitable tanks. Such tanks are to be separated from non-hazardous areas by means of cofferdams with gas-tight bulkheads. Where crude oil/slops in tanks is preheated, its temperature is to be automatically controlled and a high temperature alarm and cut-out fitted.

1.3.2 The crude oil/slops transfer and treatment system (pumps, strainers, separators, etc.) is to be located within a designated hazardous area, such as a pump-room. This area is to be separated from the boiler room and other machinery spaces by gas-tight bulkheads.

1.3.3 Where crude oil/slops is heated by steam or hot water, the outlet from the heating coils is to be led to a separate, closed observation tank located within a designated hazardous area, together with the transfer and treatment components. This tank is to be fitted with a vent pipe led to atmosphere at a safe location, and the vent outlet fitted with a suitable flame arrester.

1.3.4 Pumps are to be fitted with a pressure relief valve in closed circuit discharging to the suction side, and are to be capable of being stopped from the machinery control room and from near the boiler front, as well as locally in the compartment in which they are situated.

1.3.5 Prime movers for pumps, etc. (excluding hydraulic motor drives) are to be located in a non-hazardous machinery space. Where drive shafts pass through a pump-room bulkhead or deck, gas-tight glands are to be fitted. These glands are to be effectively lubricated from outside the pump-room, *see also Pt 5, Ch 15 Piping Systems for Oil Tankers* of the *Rules and Regulations for the Classification of Ships*.

1.3.6 The crude oil piping is, as far as practicable, to be installed with an inclination rising towards the boiler so that the oil naturally returns towards the pumps in the case of leakage or failure in delivery pressure.

1.3.7 Crude oil delivery and return pipes are to be fitted with fail-close, shut-off master valves located external to the boiler room and remotely controlled from a position near the boiler fronts and from the machinery control room. These valves are to be arranged to close automatically on failure of duct ventilation or on detection of crude oil leakage within the duct.

1.3.8 The crude oil supply line to each burner unit is to be fitted with an automatic shut-down valve arranged so that failure of the forced draught fan, boiler hood exhaust fan, flame failure at the burner or loss of the valve actuating medium will cause the valve to close. The valves are to be arranged for local operation and for manual reset.

1.3.9 The operation of the master valves or burner shutdown valves is to activate an alarm in the boiler room and in the central control room.

1.3.10 Provision is to be made for gas-freeing and inerting that portion of the crude oil piping system located in the boiler room or machinery space.

1.3.11 Suitable arrangements are to be made for change over between crude oil/slops and fuel oil so that change over can be accomplished quickly and easily.

1.4 Piping requirements

1.4.1 Fuel gas and crude oil piping is to be entirely separate from other piping systems and is not to pass through accommodation, service spaces or control stations. Such piping within the boiler room or machinery space is to be enclosed in a ventilated, gas-tight duct or be doublewalled as per either *Pt 5, Ch 16, 1.4 Piping requirements 1.4.2* or *Pt 5, Ch 16, 1.4 Piping requirements 1.4.3* respectively. For piping external to the boiler room or machinery space, or passing through enclosed non-hazardous spaces, *see Pt 5, Ch 16, 1.4 Piping requirements 1.4.6*.

1.4.2 The piping is to be installed within a ventilated, gas-tight duct, and this duct is to be connected to the bulkhead where it enters the boiler room or machinery space and to the burner unit(s) enclosure. The duct is to be provided with mechanical ventilation having a capacity of at least 30 air changes per hour and arranged to maintain a pressure less than atmospheric pressure. The ventilation outlet is to be located at a safe location where no gas-air mixture could be ignited. The duct ventilation is to be in continuous operation when fuel is in the piping. Continuous gas monitoring is to be provided in the duct to detect leaks, and arranged to automatically close the master valve in accordance with *Pt 5, Ch 16, 1.2 Fuel gas supply arrangements 1.2.4* or *Pt 5, Ch 16, 1.3 Crude oil supply arrangements 1.3.7*

1.4.3 Alternatively, the piping may be a double-walled piping system with the fuel contained in the inner pipe and the annular space between pipes pressurised with inert gas to a pressure greater than the fuel pressure. Alarms are to be provided to indicate

loss of pressure between the pipes and the master valves arranged to automatically close in accordance with *Pt 5, Ch 16, 1.2 Fuel gas supply arrangements 1.2.4* or *Pt 5, Ch 16, 1.3 Crude oil supply arrangements 1.3.7*

1.4.4 Piping connections are to be reduced to the minimum required for installation and machinery maintenance. All piping is to be suitably and adequately supported so as to avoid vibration.

1.4.5 The piping for conveying fuel gas or crude oil/slops, and for the drainage pipes from the tray specified in *Pt 5, Ch 16, 1.6 Special requirements for boilers/fired heaters 1.6.3*, is to have a minimum wall thickness as specified for fuel oil systems in *Pt 5, Ch 12 Piping Design Requirements*.

1.4.6 Gas and crude oil/slops supply and return pipes which are located external to the boiler room or machinery space in open or semi-enclosed non-hazardous areas are to be of seamless heavy gauge steel with a minimum wall thickness of Sch 80, and have fully radiographed, full penetration, butt welded joints. Pipe connections are to be of the heavy flange type. This piping is to be clearly identifiable by means of a suitable colour code. Piping passing through enclosed non-hazardous spaces will be specially considered.

1.5 Boiler room and machinery space ventilation

1.5.1 Ventilation of the boiler rooms and machinery spaces is to be at a pressure above atmospheric pressure by a separate ventilation system independent of all other ventilation systems, and providing at least 12 air changes per hour. At least two 100 per cent capacity fans are to be fitted. If the boiler, turbine, etc. is installed in a confined part of the boiler room or machinery space, the ventilation requirements apply to that part of the space only. For particular requirements relating to gas turbine ventilation, *see Pt 7, Ch 2, 6.5 Gas turbine ventilation*.

1.5.2 The ventilation system is to ensure good air circulation in all spaces, and in particular to prevent the formation of stagnant pockets of gas within the space. Gas detectors are to be fitted at appropriate locations in these spaces, particularly where air circulation may be restricted.

1.5.3 Where released gases are likely to be heavier than air as in the case of crude oil systems, extraction ducts should be located at a low level within the boiler room. Open mesh floor plates should be utilised as required to ensure efficient extraction of gases.

1.5.4 The ventilation air intakes are to be from an external non-hazardous area, at least 3 m from the boundary of any hazardous area. Ventilation outlets are to be led to atmosphere at a safe location.

1.5.5 Boilers and turbines are to be fitted with a suitable hood or casing, arranged so as to enclose as much as possible of the burners and associated valves and pipes, but without restricting the air flow to the burner registers. The hood or casing should be installed to ensure that the ventilating air sweeps across the enclosed valves, etc. and be fitted with doors as necessary for inspection of, and access to, the burner units, valves and pipes.

1.5.6 The boiler/turbine hood is to be fitted with a ventilation duct led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame-proof wire gauze. At least two 100 per cent capacity extraction fans with sparkproof impellers are to be fitted to maintain the pressure inside the hood less than that of the boiler room or machinery space. The fans are to be arranged for automatic change over to the standby fan on failure of the operational fan. The fan prime movers are to be placed outside the duct with gastight drive shaft penetration through the duct casing.

1.5.7 Means of continuous gas detection is to be provided in way of the hood and gas pipe ducting and arranged to provide an audible and visual alarm at 30 per cent lower explosive limit and shut-down of the fuel supply before the gas concentration reaches 60 per cent of the lower explosive limit.

1.6 Special requirements for boilers/fired heaters

1.6.1 The arrangement of boilers and burner systems is to comply, in general, with the requirements of *Pt 5, Ch 14 Machinery Piping Systems*, as applicable. The whole of the boiler casing is to be gastight and each boiler is to have a separate uptake.

1.6.2 The arrangement of burner units and all associated valves is to be such that the fuel gas or crude oil/slops is ignited by the flame of the fuel oil burner. A flame scanner is to be installed and arranged to ensure that the fuel supply to the burner is cut off unless satisfactory ignition has been established and maintained. A manually operated shut-off valve and flame arrester is to be fitted to each burner unit.

1.6.3 Boilers for burning crude oil/slops are to be fitted with a tray or gutterway of suitable height placed in such a way so as to collect any possible oil leakage from burners, valves or connections. The tray or gutterway is to be fitted with a drain pipe discharging into a separate, closed collecting tank in the boiler room, pump-room or other suitable location. This tank is to be

fitted with a vent pipe led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame arrester, and with provision for drainage to a suitable tank outside the machinery space.

1.6.4 Means are to be provided for the boiler to be automatically purged before firing or relighting. Arrangements are also to be provided to allow manual purging, but interlocking devices should be fitted to ensure that purging can only be carried out when the burner fuel supply valves are closed.

■ Section 1
General

1.1 Application

1.1.1 Requirements for fusion welding of pressure vessels and piping are given in *Pt 5, Ch 17 Requirements for Fusion Welding of Pressure Vessels and Piping* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for integrated propulsion systems are given in *Pt 5, Ch 18 Integrated Propulsion Systems* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

■ *Section 1* General

1.1 Application

1.1.1 Requirements for steering gear applicable to units designed to undertake self-propelled passages without external assistance are given in *Pt 5, Ch 19 Steering Arrangements* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with in addition to the requirements in this Section.

1.1.2 When a ship unit is classed as a floating offshore installation at a fixed location and the rudder is inoperative, *see Pt 4, Ch 10, 1 General*

1.1.3 Where rudders are left *in situ* on ship units, positive locking devices are to be fitted to steering gears to prevent rudders moving violently in storm conditions. Plans, together with supporting design calculations, are to be submitted for approval to show satisfactory capacity in the worst contemplated environmental conditions.

1.1.4 Consideration of the predicted extreme wind and wave loadings, unit orientation and wave headings, together with all other relevant environmental conditions at the operating site, are to be taken into account in predicting forces and moments on the rudder control systems.

1.1.5 In some circumstances, the positive locking devices required by *Pt 5, Ch 19, 1.1 Application 1.1.3* may be omitted if it can be shown that, during storm conditions, the existing (installed) hydraulic steering control system, either temporarily power-operated or left with passive trapped hydraulic fluid in the circuit but with relief valves open, is sufficient to counteract or dampen the imposed rudder moments such as to control violent movements of the rudder. However, in such cases, it may still prove necessary to carry out fatigue analysis of the rudder to tiller and support arrangements, taking into account the expected environmental sea wave velocity spectrums and structural natural frequencies to ensure satisfactory fatigue lives.

1.1.6 With reference to *Pt 5, Ch 19, 5.1 Electric power circuits 5.1.6*, *Pt 5, Ch 19, 5.2 Electric control circuits 5.2.2* and *Pt 5, Ch 19, 6.1 General 6.1.1* of the Rules for Ships, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the unit under normal service conditions.

1.2.3 **Steering gear power unit** means:

(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the unit in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the unit is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which convert directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with *Pt 5, Ch 19, 2.1 General 2.1.2*

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:

(a) readily accessible and, as far as practicable, separated from machinery spaces; and
(b) Provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:

(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure-retaining parts together with proposed rated torque and all relief valve settings.
(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.
(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All the steering gear components and the rudder stock are to be of sound reliable construction to the Surveyor's satisfaction.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5.3 Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings, and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent and a tensile strength not in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see Pt 3, Ch 13, 2 Rudders* of the Rules for Ships.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*

1.6.3 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.4 The factor of safety against slippage, *S* (i.e. for torque transmission by friction) is generally based on:

$$S = \frac{\text{the torque transmissable by friction}}{M}$$

where

M. is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.5 For conical sections, *S* is based on the following equation:

$$S = \frac{\mu A \sigma_r}{\sqrt{(W + A \sigma_r \theta)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\frac{2M}{d_m}$ in N

where

d_m is the mean contact diameter of tiller/stock interface and *M* in Nmm is defined in *Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.4*, in mm

θ = cone taper half angle in radians (e.g. for cone taper 1:10, θ = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

Table 19.1.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock, *see also Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.4* and *Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*	(a) For keyed connection, factor of safety against slippage, *S* = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, *S* = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2

(2) Hydraulic fit – tiller to stock, *see also Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.4* and *Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.5*	(a) For keyed connection, factor of safety against slippage, *S* = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, *S* = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock, *see also Pt 5, Ch 19, 1.6 Rudder, rudder stock, tiller and quadrant 1.6.3*	(a) Factor of safety against slippage, *S* = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant (this arrangement could be accepted provided theproposed rudder stock diameter in way of tillerdoes not exceed 350 mm diameter), *see* symbols	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: t_s = 0,0014 δ_t mm For 6 connecting bolts: t_s = 0,0012 δ_t mm Key(s) to be fitted Diameter of bolts, $\delta_{tb} = \dfrac{0,60\,\delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted Distance from centre of stock to centre of bolts should generally be equal to $\delta_t\left(1,0+\dfrac{0,30}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller ≥ $\dfrac{0,66\,\delta_t}{\sqrt{n_{tb}}}$
(5) Key/keyway, *see* symbols	Effective sectional area of key in shear ≥ 0,25 δ_t^2 mm^2 Key thickness ≥ 0,17 δ_t mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis), *see* symbols	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0,15\,\delta_t^3\left(b_T - b_s\right)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0,06\,\delta_t^3\left(b_T - 0,9\,\delta_t\right)}{1000 b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2

(7) Boss, *see* symbols	Depth of boss ≥ δ_t Thickness of boss in way of tiller ≥ 0,4 δ_t

Symbols	
b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm	t_s = thickness of shim for machining bolted tillers and quadrants, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle	Z_{TA} = section modulus of tiller arm, in cm^3
b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm	δ_t = Rule rudderstock diameter in way of tiller, *see Pt 3, Ch 13 Ship Control Systems* of the Rules for Ships
n_{tb} = number of bolts in the connection flanges, but generally not to be taken greater than six	δ_{tb} = diameter of bolts securing bolted tillers and quadrants, in mm

■ *Section 2* Performance

2.1 General

2.1.1 Unless the main steering gear comprises two or more identical power units, in accordance with *Pt 5, Ch 19, 2.1 General 2.1.4* or *Pt 5, Ch 19, 8.1 For oil storage units of 10 000 tons gross and upwards and every other unit of 70 000 tons gross and upwards 8.1.1*, every unit is to be provided with a main steering gear and an auxiliary steering gear, in accordance with the requirements of the Rules. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering gear and rudder stock is to be:

(a) Of adequate strength and capable of steering the unit at maximum ahead service speed, which shall be demonstrated in accordance with *Pt 5, Ch 19, 7.2 Trials*;

(b) Capable of putting the rudder over from 35° on one side to 35° on the other side with the unit at its deepest sea-going draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds;

(c) Operated by power where necessary to meet the requirements of *Pt 5, Ch 19, 2.1 General 2.1.2* and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and

(d) So designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

2.1.3 The auxiliary steering gear is to be:

(a) Of adequate strength and capable of steering the unit at navigable speed and of being brought speedily into action in an emergency;

(b) Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the unit at its deepest sea-going draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and

(c) Operated by power where necessary to meet the requirements of *Pt 5, Ch 19, 2.1 General 2.1.3* and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

2.1.4 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that the main steering gear is arranged so that, after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Main and auxiliary steering gear power units are to be:

(a) Arranged to restart automatically when power is restored after power failure;

(b) Capable of being brought into operation from a position on the navigating bridge. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the navigating bridge;
(c) Arranged so that transfer between units can be readily effected.

2.1.6 Where the steering gear is so arranged that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

2.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

2.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.2 Rudder angle limiters

2.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear only and not with the steering gear control.

■ *Section 3*
Construction and design

3.1 General

3.1.1 Rudder actuators other than those covered by *Pt 5, Ch 19, 8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight* and the 'Guidelines' are to be designed in accordance with the relevant requirements of *Pt 5, Ch 11 Other Pressure Vessels* for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of *Pt 5, Ch 11 Other Pressure Vessels*.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimise local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure, which is to be expected under the operational conditions specified in *Pt 5, Ch 19, 2.1 General 2.1.2*, taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads, *see Pt 5, Ch 19, 9 'Guidelines' for the acceptance of non-duplicated rudder actuators for oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight*.

3.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_{\rm B}}{A} \text{ or } \frac{\sigma_{\rm y}}{\rm B}$$

where

$\sigma_{\rm B}$ = specified minimum tensile strength of material at ambient temperature

$\sigma_{\rm y}$ = specified minimum yield stress or 0,2 per cent proof stress of the material at ambient temperature *A* and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilise anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength of at least the equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of *Pt 5, Ch 12 Piping Design Requirements* for Class I piping systems components. The design pressure is to be in accordance with *Pt 5, Ch 19, 3.1 General 3.1.5*

3.2.6 Hydraulic power-operated steering gears are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;
(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power-operated. The storage tank is to be permanently connected by piping, in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and where pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by *Pt 5, Ch 19, 3.3 Valve and relief valve arrangements 3.3.3*, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can be delivered through them. Under such conditions, the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions, in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by LR may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see also Pt 5, Ch 12 Piping Design Requirements*

3.4.2 Hoses should be high pressure hydraulic hoses, according to recognised standards and should be suitable for the fluids, pressures, temperatures and ambient conditions in question.

3.4.3 Burst pressure of hoses is to be not less than four times the design pressure.

Section 4
Steering control systems

4.1 General

4.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment;
(b) Where the main steering gear is arranged according to *Pt 5, Ch 19, 2.1 General 2.1.4*, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system does not need to be fitted, except in a oil storage unit of 10000 gross tonnage and upwards;
(c) For the auxiliary steering gear, in the steering gear compartment and, if power-operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear; and
(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

4.1.2 Any main and auxiliary steering gear control system, operable from the navigating bridge, is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves;
(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

4.1.3 The angular position of the rudder shall:

(a) Be indicated on the navigating bridge, if the main steering gear is power-operated. The rudder angle indication is to be independent of the steering gear control system;
(b) Be recognisable in the steering gear compartment.

4.1.4 Appropriate operating instructions with a block diagram showing the changeover procedures for steering gear control systems and steering gear actuating systems, which are to be permanently displayed in the wheelhouse and in the steering gear compartment.

4.1.5 Where the system failure alarms for hydraulic lock, *see Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.1*, are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

Section 5
Electric power circuits, electric control circuits, monitoring and alarms

5.1 Electric power circuits

5.1.1 Short-circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or be circuit protected. They are to allow excess current to pass during the normal accelerating period of the motors.

5.1.2 The alarms required by *Pt 5, Ch 19, 5.1 Electric power circuits 5.1.1* are to be provided on the bridge and in the main machinery space or control room from where the main machinery is normally controlled.

5.1.3 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

5.1.4 A low-level alarm is to be provided for each power actuating system and hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

5.1.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement, consisting of one or more electric motors.

5.1.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*

5.1.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

5.1.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and that can operate simultaneously.

5.1.9 These circuits are to be permanently separated and as widely as is practicable.

5.1.10 In units of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than what is described in *Pt 5, Ch 19, 5.1 Electric power circuits 5.1.1*, for such a motor which is primarily intended for other services.

5.2 Electric control circuits

5.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

5.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*

(b) Each separate circuit is to be provided with short-circuit protection only.

5.3 Monitoring and alarms

5.3.1 Alarms and monitoring requirements are indicated in *Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.2* and *Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.1*.

Table 19.5.1 Alarm requirements

Item	Alarm	Note
Rudder position	—	Indication, *see Pt 5, Ch 19, 4.1 General 4.1.3*
	Failure	*See Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.3*
Steering gear power units, power	Failure	—
Steering gear motors	Overload	For alarm and running indication locations,
	Single phase	*see Pt 5, Ch 19, 5.1 Electric power circuits 5.1.2* and *Pt 5, Ch 19, 5.1 Electric power circuits 5.1.3*
Control system	Failure	*See Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.3*
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be monitored. For alarm locations, *see Pt 5, Ch 19, 5.1 Electric power circuits 5.1.4*
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted
NOTE		
This alarm is to identify the system at fault and to be activated when (for example):		

• position of the variable displacement pump control system does not correspond with given order; or
• incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

5.3.2 The alarms described in *Pt 5, Ch 19, 5.3 Monitoring and alarms 5.3.1* are to be indicated on the navigating bridge and additional locations are to be described in accordance with the alarm system, as specified by *Pt 6, Ch 1, 2.3 Alarm systems*

5.3.3 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

■ *Section 6*
Emergency power

6.1 General

6.1.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply, sufficient at least to supply the steering gear power unit, which complies with the requirements of *Pt 5, Ch 19, 2.1 General 2.1.3* and also its associated control system and the rudder angle indicator, shall be provided automatically, within 45 seconds, either from the emergency source of electrical power, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*or from an independent source of power located in the steering gear compartment. This independent source of power should only be used for this purpose.

6.1.2 In every unit of 10 000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other unit for at least 10 minutes.

6.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

■ *Section 7*
Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to the testing of Class 1 pressure vessels, piping, and related fittings, including hydraulic testing apply.

7.1.2 After installation on board the unit, the steering gear is to be subjected to the required hydrostatic and running tests.

7.1.3 Each type of power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours and the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test, no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

7.2 Trials

7.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by *Pt 5, Ch 19, 2.1 General 2.1.2* and *Pt 5, Ch 19, 2.1 General 2.1.3*:

- For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
- If the unit cannot be tested at the deepest draught, alternative trial conditions may be specially considered. In this case, for the main steering gear trial, the speed of the ship unit corresponding to the maximum continuous revolutions of the main engine should apply:

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The hydraulic fluid recharging system;
(e) The emergency power supply required by *Pt 5, Ch 19, 6.1 General 6.1.1*;
(f) The steering gear controls, including transfer of control and local control;
(g) The means of communication between the steering gear compartment and the wheelhouse, also the engine room, if applicable;
(h) The alarms and indicators;
(i) Where the steering gear is designed to avoid hydraulic locking, this feature shall be demonstrated.

Test items *Pt 5, Ch 19, 7.2 Trials 7.2.1*, *Pt 5, Ch 19, 7.2 Trials 7.2.1*, *Pt 5, Ch 19, 7.2 Trials 7.2.1* and *Pt 5, Ch 19, 7.2 Trials 7.2.1* may be effected at the dockside.

■ *Section 8*
Additional requirements

8.1 For oil storage units of 10 000 tons gross and upwards and every other unit of 70 000 tons gross and upwards

8.1.1 The main steering gear is to comprise of two or more identical power units, complying with provisions of *Pt 5, Ch 19, 2.1 General 2.1.4*

8.2 For oil storage units of 10 000 tons gross and upwards

8.2.1 Subject to *Pt 5, Ch 19, 8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight*, the following are to be complied with:

(a) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in no more than 45 seconds after the loss of one power actuating system.
(b) The main steering gear is to comprise of either:
    (i) two independent and separate power actuating systems, each capable of meeting the requirements of *Pt 5, Ch 19, 2.1 General 2.1.2*; or
    (ii) at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of *Pt 5, Ch 19, 2.1 General 2.1.2*. Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system is automatically isolated so that the other actuating system or systems remain fully operational.
(c) Steering gears other than the hydraulic type are to achieve equivalent Standards.

8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

8.3.1 Solutions other than those set out in *Pt 5, Ch 19, 8.2 For oil storage units of 10 000 tons gross and upwards 8.2.1*, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety Standard is achieved and that:

(a) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 seconds; and

(b) Where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design, including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance. In consideration of the foregoing arrangements, regard will be given to the 'Guidelines' in *Pt 5, Ch 19, 9 'Guidelines' for the acceptance of non-duplicated rudder actuators for oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight*

8.3.2 Manufacturers of the steering gear who intend their product to comply with the requirements of the 'Guidelines', are to submit full details when plans are forwarded for approval.

■ *Section 9*
'Guidelines' for the acceptance of non-duplicated rudder actuators for oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

9.1 Materials

9.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder stock are to be made of duly tested ductile materials complying with recognised Standards. Materials for pressure retaining components are to be in accordance with recognised pressure vessel Standards. These materials are not to have an elongation less than 12 per cent, nor a tensile strength in excess of 650 N/mm^2.

9.2 Design

9.2.1 **Design pressure**. The design pressure should be assumed to be at least equal to the greater of the following:

(a) 1,25 times the maximum working pressure to be expected under the operating conditions required in *Pt 5, Ch 19, 2.1 General 2.1.2*

(b) The relief valve(s) setting.

9.2.2 **Analysis**. In order to analyse the design, the following are required:

(a) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.

(b) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.

(c) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

9.2.3 **Dynamic loads for fatigue and fracture mechanics analysis**. The assumption for dynamic loading for fatigue and fracture mechanics analysis where required by *Pt 5, Ch 19, 3.1 General 3.1.5*, *Pt 5, Ch 19, 8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight* and *Pt 5, Ch 19, 9.2 Design 9.2.2* are to be submitted for appraisal. Both the case of high cycle and cumulative fatigue are to be considered.

9.2.4 **Allowable stresses**. For the purposes of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$\sigma_{\mathrm{m}} \leq f$

$\sigma_{1} \leq 1{,}5f$

$\sigma_{\mathrm{b}} \leq 1{,}5f$

$\sigma_{1} + \sigma_{\mathrm{b}} \leq 1{,}5f$

$\sigma_{\mathrm{m}} + \sigma_{\mathrm{b}} \leq 1{,}5f$

where

f = the lesser of $\frac{\sigma_{\mathrm{B}}}{A}$ or $\frac{\sigma_{\mathrm{y}}}{\mathrm{B}}$

σ_{b} = equivalent primary bending stress

σ_{m} = equivalent primary general membrane stress

σ_{y} = specified minimum yield stress or 0,2 per cent proof stress of material at ambient temperature

σ_{B} = specified minimum tensile strength of material at ambient temperature

σ_{1} = equivalent primary local membrane stress *A* and *B* are as follows:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	4	4,6	5,8
B	2	2,3	3,5

9.2.5 **Burst test**. Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by *Pt 5, Ch 19, 9.2 Design 9.2.2* need not be provided.

The minimum bursting pressure should be calculated as follows:

$$P_{\mathrm{b}} = PA\frac{\sigma_{\mathrm{Ba}}}{\sigma_{\mathrm{B}}}$$

where

A = as from Table in *Pt 5, Ch 19, 9.2 Design 9.2.4*

P = design pressure, as defined in *Pt 5, Ch 19, 9.2 Design 9.2.1*

P_{b} = minimum bursting pressure

σ_{B} = tensile strength, as defined in *Pt 5, Ch 19, 9.2 Design 9.2.4*

σ_{Ba} = actual tensile strength.

9.3 Construction details

9.3.1 **General**. The construction should be such as to minimise local concentrations of stress.

9.3.2 **Welds.**

(a) The welding details and welding procedures should be approved.
(b) All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be a full penetration type or of equivalent strength.

9.3.3 **Oil seals**. Oil seals forming part of the external pressure boundary are to comply with *Pt 5, Ch 19, 3.2 Components 3.2.3* and *Pt 5, Ch 19, 3.2 Components 3.2.4*.

9.3.4 **Isolating valves** are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

9.3.5 **Relief valves** for protecting the rudder actuator against over-pressure as required in *Pt 5, Ch 19, 3.3 Valve and relief valve arrangements 3.3.3* are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure expected under operating conditions required by *Pt 5, Ch 19, 2.1 General 2.1.2*

(b) The minimum discharge capacity of the relief valve(s) is to be not less than 110 per cent of the total capacity of all pumps which provided power for the actuator. Under such conditions, the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

9.4 Non-destructive testing

9.4.1 The rudder actuator should be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognised Standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

9.5 Testing

9.5.1 Tests, including hydrostatic tests, of all pressure parts at 1,5 times the design pressure should be carried out, subject to any limitations imposed by valves and other components. Where additional testing of systems or subsystems following final assembly is required, the test pressure may be subject to any limitations imposed by valves and other components.

9.5.2 When installed on board the unit, the rudder actuator should be subjected to a hydrostatic test at the pressure, defined in *Pt 5, Ch 19, 9.5 Testing 9.5.1*, as well as a running test.

9.6 Additional requirements for steering gear fitted to units with Ice Class notations

9.6.1 *See Pt 3, Ch 6 Units for Transit and Operation in Ice*

Section 1
General

1.1 Application

1.1.1 Requirements for azimuth thrusters are given in *Pt 5, Ch 20 Azimuth Thrusters* of the *Rules and Regulations for the Classification of Ships, July 2016*, which should be complied with.

1.1.2 Where Thruster Condition Monitoring (ThCM) Descriptive Note has been requested, refer to ShipRight Machinery Planned Maintenance and Condition Monitoring, Section 6.

Section 1
General

1.1 Application

1.1.1 Requirements for condition monitoring systems are given in *Pt 5, Ch 21 Requirements for Condition Monitoring Systems and Machinery Condition-Based Maintenance Systems* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for the redundancy of propulsion and steering machinery are given in *Pt 5, Ch 22 Propulsion and Steering Machinery Redundancy* of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to self-elevating units with machinery of the rack and pinion type used to raise and lower the position of the hull with respect to the legs, or other supporting structure above the surface of the sea.

1.1.2 Machinery for self-elevating units utilising other systems will be specially considered.

1.2 Definitions

1.2.1 The following definitions are applicable to this Chapter:

(a) **Normal jacking load**. The maximum design elevated weight of the hull, including variable load, to be raised/lowered by the jacking unit, during normal jacking operation.
(b) **Pre-load jacking load**. The maximum design elevated weight of the hull, including pre-load ballast load, to be lowered by the jacking unit in the event of sudden leg penetration during pre-load operation.
(c) **Pre-load holding load**. The maximum design elevated weight of the hull, including pre-load ballast, to be held by the jacking unit during the pre-load operation.
(d) **Ultimate holding load**. The maximum load capable of being held by the jacking unit, in an emergency situation, without causing slippage of the jacking gear machinery braking device.
(e) **Storm survival load**. The maximum static design load in the leg to be supported by the jacking and/or fixation systems.
(f) **Fixation system**. The mechanical locking device, with an engaging mechanism, used to provide positive engagement between the hull support structure and the leg chord.
(g) **Jacking gear unit**. The individual reduction gear assembly, comprising drive motor, coupling, enclosed reduction gearing and main pinion normally attached to the jack-house.
(h) **Jack-house**. The structure surrounding the leg chord into which multiple jacking units are installed.

1.3 Submission of plans and particulars

1.3.1 The following plans, together with the necessary particulars of the jacking mechanism are to be submitted for consideration:

- General arrangement of the self-elevating machinery, including a cross-sectional arrangement.
- Full design details of all transmission gear elements including gear tooth geometry and machining details.
- Full design details of all transmission shafting, couplings, coupling bolts, interference assemblies, keys, keyways.
- Bearing details.
- Enclosed gear casing details and mounting arrangements.
- All assembly design tolerances are to be submitted, including, where applicable, allowances for wear during normal operation such as rack guides.
- Prime mover specifications including braking devices.
- Drawing of main pinion and rack tooth profile showing full geometric details.

- Full design details of the fixation system, where fitted.
- A load-time spectrum for the envisaged dynamic operational requirements of the self-elevating machinery for the unit is to be specified.
- A simulated load analysis for the main pinion/rack tooth mesh during wet/dry tow conditions.

1.4 Material specifications

1.4.1 Specifications for materials for the gearing and other mechanical components giving chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans required by *Pt 5, Ch 23, 1.3 Submission of plans and particulars 1.3.1*.

1.4.2 Where the teeth of a pinion or gear wheel are to be surface-hardened (i.e. carburised, nitrided, tufftrided or induction-hardened) the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2*
Materials

2.1 Material properties

2.1.1 Materials used for the construction of the jacking gear machinery are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or a National Standard acceptable to LR. *See Ch 1, 2.2 LR Approval – General* of the Rules for Materials for additional requirements for materials.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

■ *Section 3*
Design

3.1 General

3.1.1 Self-elevating systems are to be designed with redundancy such that a single failure of any component will not cause an uncontrolled descent of the unit or impair the safety of the unit. Each leg is to be provided with a load indication and an overload alarm at a manned control station.

3.1.2 Braking devices are to fail safe in the engaged position in the event of a failure or interruption of the power supply to the lifting machinery.

3.1.3 Unless otherwise agreed by LR, the system is to be designed such that the rack tooth is the weakest component in the self-elevating machinery with regard to static mechanical strength.

3.1.4 The jacking system, together with the fixation system if fitted, is to be capable of adequately lifting and supporting the hull, or leg installation under all operating, survival and tow conditions.

3.1.5 The requirement for emergency jacking of the hull with full or part pre-load to stabilise the unit in the event of sudden leg penetration is to be considered.

3.1.6 The self-elevating mechanism is to be designed to pre-load the foundation to the design conditions and be capable of supporting a load not less than the maximum load for which the leg has been designed.

3.1.7 Unless otherwise agreed, the minimum design operating temperature of the jacking gear machinery is to be in accordance with *Pt 3, Ch 1, 4.4 Minimum design temperature*

3.1.8 In selecting the prime movers for the self-elevating machinery, consideration is to be given to the effects of friction at the mesh of the pinion and rack, and between legs and guides, together with uneven load distribution.

3.1.9 The control station from which the elevating and lowering machinery is operated is to be provided with all necessary monitoring, alarms and controls including hull alignment, prime mover running load pin position, running indication, overload alarms and indication of availability of applicable power sources, as appropriate.

3.2 Enclosed gearing

3.2.1 All enclosed transmission gearing is to be designed in accordance with a National Standard acceptable to LR.

3.2.2 The design is to have sufficient load capacity to meet the minimum requirements of *Pt 5, Ch 23, 3.2 Enclosed gearing 3.2.2* and *Pt 5, Ch 23, 3.2 Enclosed gearing 3.2.2* and *Pt 5, Ch 23, 3.2 Enclosed gearing 3.2.3* to *Pt 5, Ch 23, 3.2 Enclosed gearing 3.2.5*.

Table 23.3.1 Tooth flank bending strength

Tooth root bending strength	Required factor of safety s_{Fmin}
Dynamic operation:	
Normal jacking of hull and legs	1,5
Pre-load jacking of hull (*see* Note 1)	1,5
Static operation:	
Normal holding load (without fixation system engaged) (*see* Note 2)	1,5
Pre-load holding	1,5
Symbols	
s_{Fmin} is defined as $\frac{\sigma_{\text{FP}}}{\sigma_{\text{F}}}$ σ_{FP} = allowable tooth root bending stress σ_{F} = calculated tooth root bending stress	
NOTES 1. Based on 50 hours operation. 2. It is considered that where a fixation system is properly engaged the loading applied to the jacking gears will be minimal.	

Table 23.3.2 Tooth flank Hertzian stress

Tooth flank Hertzian stress	Required factor of safety s_{Hmin}
Dynamic operation:	1,0
Static operation:	1,0
Symbols	
s_{Hmin} is defined as $\frac{\sigma_{\text{FP}}}{\sigma_{\text{F}}}$	

σ_{FP} = allowable Hertzian bending stress
σ_{F} = calculated Hertzian bending stress

3.2.3 The following design values are to be used in the assessment of the gear design unless otherwise agreed:

- Application factor, K_A :

  Electric motor drive 1,0
- Load Sharing Factor K_y :

  With pinion load monitoring 1,0

  Without pinion load monitoring 1,2.

3.2.4 Material endurance strength limits are to comply with the requirements of a National Standard acceptable to LR.

3.2.5 Consideration is to be given to the loads applied to the gears during wet/dry tow conditions, as the gear teeth may be subjected to full load reversal. The design will be given consideration based on the simulated load analysis for the main pinion/rack tooth mesh.

3.3 Main pinion and rack

3.3.1 The design of the final (main) pinion and rack is subject to special consideration but the requirements of *Pt 5, Ch 23, 3.3 Main pinion and rack 3.3.2* to *Pt 5, Ch 23, 3.3 Main pinion and rack 3.3.7* are to be complied with.

3.3.2 The nominal contact ratio of the mesh is not to be less than 1,05, taking into consideration the cumulative effects of the design and assembly tolerance values and allowable wear during operation of the guides/rack tips.

3.3.3 The material hardness of the pinion is to be not less than that of the rack tooth material.

3.3.4 The pinion is to have a factor of safety on tooth root bending of not less than 1,5 for both static and dynamic loading conditions.

3.3.5 Hertzian tooth flank contact stress is generally not to be greater than three times the yield strength of the rack material, or not greater than 3,5 times the yield for pre-load jacking.

3.3.6 The ultimate strength (collapse load) of the main pinion tooth is not to be less than 1,1 times that of the rack tooth.

3.3.7 Consideration is to be given to the loads being applied to the main pinion mesh during wet/dry tow conditions where full load reversal may be expected.

3.4 Shafting

3.4.1 Nominal shaft stresses for the plain section solid shafting are to be calculated as follows:

$$\sigma_b = \frac{32000M}{\pi d_o^3}$$

$$\tau = \frac{16000T}{\pi d_o^3}$$

where

τ = calculated torsional shaft stress, in N/mm^2

T = shaft torque, in Nm

d_o = shaft outside diameter, in mm

σ_b = calculated bending shaft stress, in N/mm^2

M = bending moment, in Nm.

3.4.2 The maximum stresses due to bending and torsion are not to exceed the values shown in *Pt 5, Ch 23, 3.8 Rack fixation system 3.8.1*. The assessment of the maximum stresses should take into account the system overload conditions. The allowable stress limits in *Pt 5, Ch 23, 3.8 Rack fixation system 3.8.1* include an allowance for stress concentrations at keyways, fillets shrink assemblies or other areas of stress concentration, not exceeding 3,0. Where an effective stress concentration exceeds this value, the design will be specially considered.

3.4.3 When designing a shaft for a finite number of rotating cycles, the allowable stresses may be increased by the factors in *Pt 5, Ch 23, 3.4 Shafting 3.4.3*.

Table 23.3.3 Shaft stress multipliers

Cycles	Factor
Up to 1000 cycles	2,4
Over 1000 to 10 000 cycles	1,8
Over 10 000 to 100 000 cycles	1,4
Over 100 000 to 1 million cycles	1,1
1 million cycles and over	1,0

3.4.4 Shaft materials having properties outside the range covered by *Pt 5, Ch 23, 3.8 Rack fixation system 3.8.1* will be specially considered.

3.5 Interference assemblies

3.5.1 A minimum factor of safety on slippage of 2,0 is to be achieved based on the maximum load.

3.6 Bearings

3.6.1 The capacity of the sleeve or anti-friction shaft bearings is to be such as to carry adequately the radial and thrust loads which would be induced under all operating conditions.

3.6.2 Hydrodynamic radial bearings are to be lined with babbitt or other material suitable for the intended application and duty. They are to be properly installed and secured in the housing against axial and rotational movement.

3.6.3 Selection of the particular design of sleeve bearing is to be based on an evaluation of the journal velocity, surface loading, hydrodynamic film thickness, and calculated bearing temperature under all operating conditions.

3.6.4 Selection of rolling element bearings is to be based upon the bearing manufacturer's recommendations for the design loading and application.

3.7 Braking device

3.7.1 Braking devices are to have a combined static friction torque capacity, considering the mechanical efficiency of the drive gear, such that no fewer than 1,3 times the maximum design load, to be supported during normal operation, may be held without brake slippage.

3.7.2 Means are to be provided such that, in the event of failure of one or more of the self-elevating machinery units, the defective unit(s) can be mechanically isolated such that the effectiveness of the remaining units in raising/lowering the hull is not impaired.

3.8 Rack fixation system

3.8.1 When a rack fixation system is fitted, the design will be subject to special consideration.

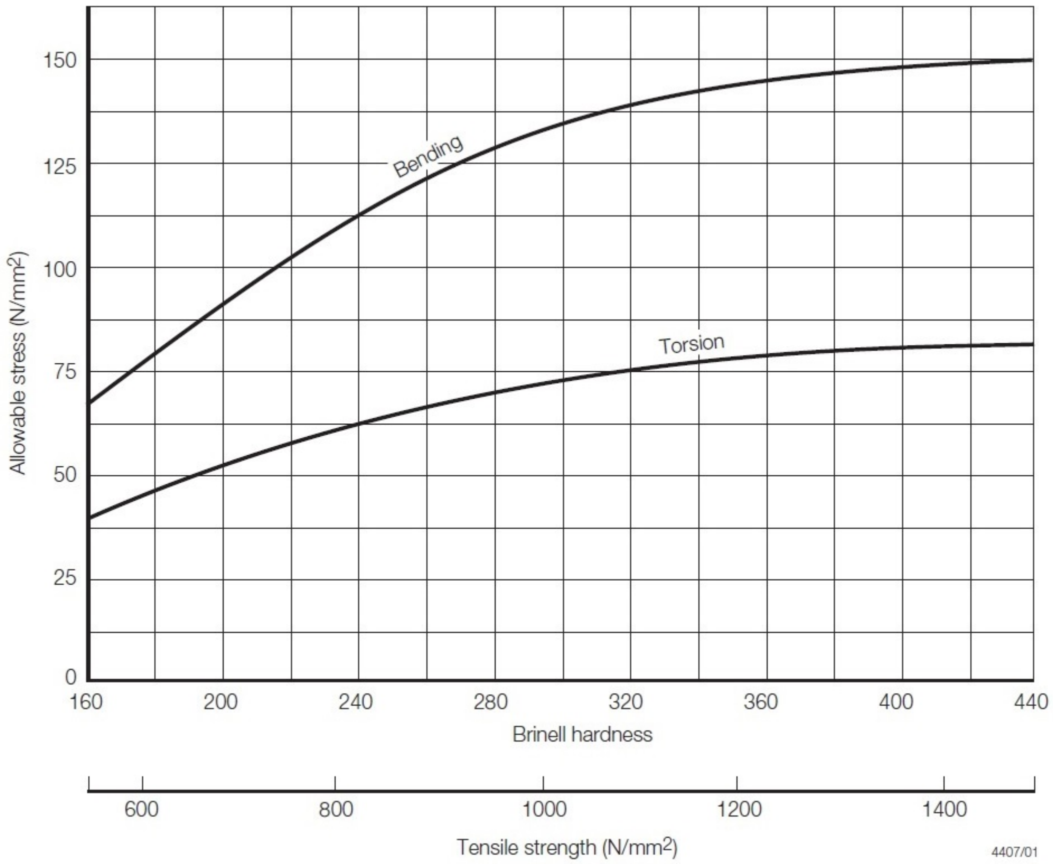


Figure 23.3.1 Allowable stress - Shafting

■ *Section 4* **Construction**

4.1 Assembly design

4.1.1 The individual jacking gear units are to be designed such that each unit can be removed separately for inspection, maintenance and repair. Adequate arrangements for dismantling, including lifting devices, are to be provided.

4.1.2 Unless otherwise agreed, all gearing, except the main climbing pinion, are to operate in oil bath enclosures. Main pinions and racks are to be supplied with a suitable lubricant during all jacking operations.

4.1.3 Adequate inspection openings are to be provided to enable the teeth of pinions and gear wheels, and their attachment to the shafts, to be readily examined.

Section 5
Inspection and testing

5.1 At jacking machinery manufacturers' works

5.1.1 The complete, assembled, jacking gear unit is to be subjected to a partial load running test with the first assembly for each new building tested to the maximum design jacking load (a minimum of one complete revolution of the main pinion) and the maximum static pre-load holding.

5.1.2 Upon satisfactory testing of the first jacking gear unit, the assembly is to be disassembled for inspection of all main components.

5.2 At the offshore unit construction site

5.2.1 Inspection and testing during construction and assembly is to be carried out to a plan/schedule acceptable to LR, but is to include the following:

(a) Jacking trials to verify satisfactory operation of the jacking machinery at all design jacking and holding load conditions.
(b) Jacking of hull/legs to the full extent of design travel to demonstrate satisfactory alignment of leg, racks, pinions and guides.
(c) Operation of the fixation system at various positions of leg/hull travel.
(d) Operation of the braking devices at the maximum design load to verify effective holding without slippage.

Section 6
Operation in ice

6.1 Additional requirements

6.1.1 *See Pt 3, Ch 6 Units for Transit and Operation in Ice* for additional requirements for operation in ice.

Contents

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all offshore units defined in *Pt 1, Ch 2 Classification Regulations*. Where applicable, the relevant requirements for control, alarm and safety systems as stated in *Pt 6, Ch 1 Control Engineering Systems*of the Rules for Ships are to be complied with.

1.1.2 Control engineering systems are to:

- provide control of required services and habitability requirements during defined operational conditions;
- provide control of the engineering systems necessary to ensure availability of essential and emergency safety systems during all normal and reasonably foreseeable abnormal conditions;
- provide control of the engineering systems necessary to ensure transitional power supplies remain available;
- be suitably protected against damage to itself under fault conditions and to prevent injury to personnel; and
- not fail in a way which may cause machinery and systems located in hazardous areas to create additional fire or explosion risk.

1.1.3 These requirements apply to manned offshore units. Special consideration will be given to unmanned offshore units which are controlled from the shore or from another offshore installation.

1.1.4 Where reference is made in this Chapter to the requirements of the Rules for Ships, references therein to ‘ship(s)’ are to be understood to apply to ‘unit(s)’.

1.2 Documentation required for design review

1.2.1 The documentation described in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.2* to *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.9* is to be submitted for design review.

1.2.2 Where control, alarm and safety systems are intended for machinery or equipment as defined in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.3*, the documentation stated in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.2* of the Rules for Ships is to be submitted.

1.2.3 Documentation for the control, alarm and safety systems of the following is to be submitted as applicable:

(a) **Propulsion and positioning systems:**

- Controllable pitch propellers.
- Dynamic positioning systems.
- Positional mooring and single point mooring systems.
- Propelling machinery including essential auxiliaries.
- Steering gear.

- Thruster-assisted positional mooring systems.
- Thruster units.

(b) **Utilities and services:**

- Air compressors.
- Bilge and ballast systems.
- Diving systems including compression chambers.
- Electric generating plant.
- Fixed water based local application fire-fighting systems.
- Evaporating and distilling systems.
- General service plant air and control and instrument air systems.
- Heating Ventilation and Air Conditioning (HVAC) systems including arrangements provided in respect of *Pt 6, Ch 1, 1.3 Control, alarm and safety equipment 1.3.3*.
- Incinerators.
- Inert gas generators.
- Main propelling machinery including essential auxiliaries.
- Lifting appliances.
- Mechanical refrigeration systems.
- Fuel oil transfer and storage (purifiers and oil heaters).
- Oily water separators.
- Steam raising plant (boilers and their ancillary equipment).
- Cargo and ballast pumps in hazardous areas.
- Tempered water systems.
- Waste heat boiler.
- Windlasses.
- Valve position indicating systems, *see Pt 6, Ch 1, 2.7 Valve control systems*.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified by other Sections of the Rules).
- Cargo tank, storage tank, ballast tank and void space instrumentation where specified by other Sections of the Rules (e.g. water ingress detection, gas detection).
- Thermal fluid heaters.

(c) **Process plant equipment:**

- Coalescers, skimmers and dehydrators.
- Export pumps and compressors.
- Gas compressors.
- Gas lift systems.
- Glycol contactors and regenerators.
- Heat exchangers.
- HP and LP flare systems.
- Process analysers.
- Production and test separator vessels.
- Production transfer and storage systems.
- Sand detection systems.
- Scrubbers.
- Sphere launching and receiving systems.
- Surge, flash and knock out drums.
- Water, gas and chemical injection systems.
- Well head, choke and header systems.
- Wireline systems.

(d) **Drilling plant equipment:**

- Blow out preventer stacks and diverter systems.

- Cement and barytes storage and handling systems.
- Choke and kill systems.
- Drawworks and eddy current brakes.
- Mud logging systems.
- Mud and cement pumps.
- Mud treatment systems.
- Rotary table.
- Wireline systems.

(e) **Riser systems.**

1.2.4 **System operational concept**. A description of how the control, alarm and safety systems for the main and auxiliary machinery and systems essential for the propulsion and safety of the unit provide effective means for operation and control during all unit operational conditions.

1.2.5 **Alarm systems**. Details of the overall alarm system, linking the main control station, subsidiary control stations, workstation(s) for navigation and manoeuvring and where applicable, the bridge area, the accommodation and other areas where duty personnel may be present are to be submitted.

1.2.6 **Programmable electronic systems**. In addition to the documentation required by *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.2* and *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.6* of the Rules for Ships, details of self-monitoring techniques are to be submitted.

1.2.7 **Wireless data communication**. For wireless data communication equipment the documentation required by *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.7* of the Rules for Ships is to be submitted.

1.2.8 **Control stations**. Documentation required to be submitted is given in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.8* of the Rules for Ships.

1.2.9 **Approved system**. Where it is intended to employ a standard system which has been previously approved, documentation is not required to be submitted, providing there have been no changes in the applicable Rule requirements. The building port, where applicable, the specific project and date of the previous approval are to be advised.

1.3 Control, alarm and safety equipment

1.3.1 The requirements for control, alarm and safety equipment are given in *Pt 6, Ch 1, 1.3 Control, alarm and safety equipment*of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.3.2 For fire and gas detection alarm systems, *see Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors* and for programmable electronic systems, *see Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements 2.10.5* and *Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.3* of the Rules for Ships.

1.3.3 Where equipment requires a controlled environment, alternative arrangements, whether permanently installed or of a temporary nature, are to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see also Pt 5, Ch 14, 12.4 Miscellaneous machinery 12.4.1* in *Pt 5, Ch 14, 12 Control, alarm and safety systems of machinery* of the Rules for Ships. Details of these arrangements are to be submitted for consideration.

1.4 Alterations and additions

1.4.1 The requirements for alterations and additions are given in *Pt 6, Ch 1, 1.4 Alterations and additions*of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.4.2 For ESD systems, *see Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*, software modifications are to be undertaken in accordance with IEC 61508-1:2010, *Functional safety of electrical/electronic/ programmable electronic safety-related systems – Part 1: General requirements*, Section 7.16, or alternative relevant International or National Standard.

1.5 Definitions

1.5.1 Definitions are given in *Pt 6, Ch 1, 1.5 Definitions*of the Rules for Ships, which are to be complied with.

Section 2
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment defined in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.3*, the applicable features contained in *Pt 6, Ch 1, 2.1 General*of the Rules for Ships are to be incorporated in the system design.

2.2 Control stations for machinery and equipment

2.2.1 The requirements for control stations for machinery and equipment are given in*Pt 6, Ch 1, 2.2 Control stations for machinery*of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.2.2 Means of communication are to be provided as applicable between the main control station, subsidiary stations, the workstation(s) for navigation and manoeuvring, the bridge area where applicable, the unit manager's office, the drill floor, the tool pusher's office and the accommodation for operating personnel.

2.2.3 For requirements regarding general emergency alarm systems, *see also Pt 7, Ch 1, 3.3 General emergency alarm systems*.

2.3 Alarm systems

2.3.1 The general requirements for alarm systems are given in *Pt 6, Ch 1, 2.3 Alarm systems, general requirements* of the Rules for Ships, which are to be complied with as required.

2.4 Safety systems

2.4.1 Where safety systems are provided the requirements of *Pt 6, Ch 1, 2.4 Safety systems, general requirements* of the Rules for Ships are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in *Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.3*, including those safeguards required by *Pt 5 MAIN AND AUXILIARY MACHINERY*. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.4.2 For emergency shut-down systems, *see also Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*.

2.5 Control systems, general requirements

2.5.1 The requirements for control systems are given in *Pt 6, Ch 1, 2.5 Control systems, general requirements*of the Rules for Ships, which are to be complied with.

2.6 Control for main propulsion machinery

2.6.1 Where a control system for propulsion machinery is to be fitted, the requirements of*Pt 6, Ch 1, 2.6 Bridge control for main propulsion machinery* of the Rules for Ships are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTES

(a) The workstation(s) for navigation and manoeuvring will be located on the bridge of the unit, where such is provided. Where there is no designated bridge area, the requirements of this sub-Section remain applicable to the workstation(s) for navigation and manoeuvring, wherever their location.
(b) Where separate workstations are provided for navigation and for manoeuvring, the requirements of this Section, and those of *Pt 6, Ch 1, 4.2 Alarm system for machinery*, are applicable to the former.
(c) Where the Rules for Ships refer to 'bridge control system', this should be understood to apply to propulsion control system.

2.6.2 Instrumentation to indicate the following is to be fitted at the workstation(s) for navigation and manoeuvring:

(a) Propeller speed.

(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller, *see also Pt 5, Ch 7, 5 Control and monitoring*of the Rules for Ships.
(c) Direction and magnitude thrust.
(d) Clutch position, where applicable.
(e) Shaft brake position, where applicable.
(f) For an azimuth thruster, direction and magnitude of thrust, and alarms and indications as detailed in *Pt 5, Ch 20, 4.2 Monitoring and alarms 4.2.1* in *Pt 5, Ch 20 Azimuth Thrusters* of the Rules for Ships.

2.6.3 Azimuth thrust direction is to be controlled from the workstation(s) for navigation and manoeuvring, under all seagoing and manoeuvring conditions.

2.6.4 Two means of communication are to be provided between the workstation(s) for navigation and manoeuvring and the main control station in the machinery space. One of these means may be the propulsion control system; the other is to be independent of the main electrical power supply, *see also Pt 6, Ch 1, 2.2 Control stations for machinery and equipment 2.2.2* and *Pt 5, Ch 1, 4.8 Communications* of the Rules for Ships.

2.7 Valve control systems

2.7.1 The requirements for valve control systems are given in *Pt 6, Ch 1, 2.7 Valve control systems* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.7.2 For ballast controls of column-stabilised units, *see also Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units*.

2.7.3 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see Pt 4, Ch 7, 10 Scuppers and sanitary discharges*.

2.8 Ballast control systems for column-stabilised units

2.8.1 Column-stabilised units are to be provided with a ballast control system which meets the requirements of *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units 2.8.2* to *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units 2.8.8*. The requirements for intact and damage stability and related definitions used in this Section are given in *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*, to which reference should be made.

2.8.2 A centralised ballast control station is to be provided from which all ballast operations can be performed. It is to be situated above zones of immersion after damage, as high as possible, as near a central position on the unit as is practicable, and adequately protected from the weather.

2.8.3 Control and instrumentation for the following is to be provided at the centralised control station:

(a) Ballast pump stop/start arrangements, status indicators, and control facilities.
(b) Ballast valve controls and position indication.
(c) Ballast tank level indication.
(d) Tank level indication of all tanks containing quantities of liquid that could affect stability of the unit, including fuel oil, fresh water, drilling water, and other stored liquids.
(e) Unit draught, heel and trim indication.
(f) Remote controls and indicators for watertight doors and hatch covers and other closing appliances, *see Pt 7, Ch 1, 10 Protection against flooding*.
(g) Bilge and flood alarms, *see Pt 7, Ch 1, 10 Protection against flooding*.
(h) Mooring line tension indication.

2.8.4 A permanently installed means of communication, independent of the unit's main source of electrical power, is to be provided between the centralised ballast control station and spaces that contain ballast pumps and services necessary for ballast operations, including local hand controls called for in *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units 2.8.5*.

2.8.5 In addition to the centralised controls required by *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units 2.8.3* and *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units 2.8.3*, permanently installed local controls are to be provided to allow operation in the event of failure of the centralised controls.

2.8.6 The independent local controls for each ballast pump and its associated ballast tank valves are to be located in the same location, and a diagram of that part of the system is to be permanently displayed at the local control position.

2.8.7 The local controls are to be in readily accessible positions, and the associated access routes are to be situated inboard of the penetration zones after defined damage, *see Pt 4, Ch 7, 3.2 Damage zones*. They are also to remain accessible and protected from the weather when the unit is in the intact and damaged condition.

2.8.8 Valve controls are to comply with *Pt 6, Ch 1, 2.7 Valve control systems* and, in addition, remote valve position indication systems are to function as independently as practicable of the control systems, *see* also *Pt 5, Ch 13, 5 Ballast system* and particularly *Pt 5, Ch 13, 5.4 Control of pumps and valves*.

2.9 Programmable electronic systems – General requirements

2.9.1 The requirements for programmable electronic systems are given in*Pt 6, Ch 1, 2.10 Programmable electronic systems - General requirements* of the Rules for Ships, which are to be complied with.

2.10 Data communication links

2.10.1 The requirements for data communication links are given in *Pt 6, Ch 1, 2.11 Data communication links* of the Rules for Ships, which are to be complied with.

2.11 Additional requirements for wireless data communication links

2.11.1 The requirements for wireless data communication links are given in*Pt 6, Ch 1, 2.12 Additional requirements for wireless data communication links* of the Rules for Ships, which are to be complied with. The requirements are in addition to *Pt 6, Ch 1, 2.10 Data communication links* and apply to systems incorporating wireless data communication links.

2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.12.1 The requirements for programmable electronic systems incorporated in control, alarm or safety systems for essential services, as defined by *Pt 6, Ch 2, 1.6 Definitions* or safety critical systems, are given in*Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.12.2 Input and output connections for safety critical systems (including emergency shut-down push button signals) are to be hard-wired, unless shown to meet the relevant requirements of *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*, for emergency shutdown systems. The transmission of the alarm and status information by digital means between the system and the supervisory workstation is permissible.

2.13 Programmable electronic systems – Additional requirements for integrated systems

2.13.1 The additional requirements for programmable electronic systems for integrated systems are given in *Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems* of the Rules for Ships, which are to be complied with.

■ *Section 3*
Ergonomics of control stations

3.1 Control station layout

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in *Pt 6, Ch 1, 3.2 Control station layout* of the Rules for Ships.

3.2 Physical environment

3.2.1 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements in *Pt 6, Ch 1, 3.3 Physical environment* of the Rules for Ships, are to be complied with.

3.3 Operator interface, controls, display

3.3.1 The requirements in *Pt 6, Ch 1, 3.4 Operator interface* to *Pt 6, Ch 1, 3.6 Displays* of the Rules for Ships apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

■ *Section 4* Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 The general requirements for unattended machinery space(s) are given in *Pt 6, Ch 1, 4.1 General* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.1.2 The requirements of this Section apply to all types of thrusters incorporated in the propulsion or positioning systems of the unit.

4.1.3 For this Section where the Rules for Ships refer to ‘bridge’, this is to be understood to apply to workstation(s) for navigation and manoeuvring, the bridge, if fitted or otherwise a continuously attended control station, as appropriate for the operating condition of the unit.

4.1.4 For this Section where the Rules for Ships refer to ‘engineering personnel’, this is to be understood to apply to maintenance personnel.

4.2 Alarm system for machinery

4.2.1 The requirements for the alarm system for machinery are given in *Pt 6, Ch 1, 4.2 Alarm system for machinery* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.2.2 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of *Pt 6, Ch 1, 2.3 Alarm systems*.

4.3 Remote control of propulsion machinery

4.3.1 Where propulsion machinery is installed, it is to be provided with a remote control system operable at the workstation(s) for navigation and manoeuvring. The system is to satisfy the requirements of *Pt 6, Ch 1, 2.6 Control for main propulsion machinery*.

4.4 Control stations for machinery

4.4.1 Control station(s) are to be provided in the vicinity of the propulsion machinery and at workstation(s) for navigation and manoeuvring, and are to satisfy the requirements of *Pt 6, Ch 1, 2.2 Control stations for machinery and equipment*.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted to protect all unattended spaces together with an audible and visual alarm system. The system is to satisfy the requirements of *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems*.

4.6 Bilge level detection

4.6.1 The requirements for bilge level detection are given in *Pt 6, Ch 1, 4.7 Bilge level detection*of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.6.2 A minimum of two independent systems of bilge level detection is to be provided in each machinery space that is situated below the water line. In addition each branch bilge as required by *Pt 5, Ch 13, 4 Bilge drainage of machinery spaces* of the Rules for Ships is to be provided with a level detector.

4.7 Supply of electric power – General

4.7.1 For units which operate with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For units operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see Pt 6, Ch 2, 2.2 Number and rating of generators and converting equipment*.

■ *Section 5*
Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 The requirements for machinery operated from a centralised control station are given in *Pt 6, Ch 1, 5.1 General requirements* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.1.2 The controls, alarms and safeguards required by *Pt 5 MAIN AND AUXILIARY MACHINERY* and by *Pt 6, Ch 1, 4.6 Bilge level detection* together with a fire detection system satisfying the requirements of *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems* are to be provided. However, the automatic operation of machinery and certain safeguards required by *Pt 5 MAIN AND AUXILIARY MACHINERY* may be omitted. Where such safeguards are omitted, due consideration is to be given to the reaction time required for manual intervention, following indication that a system or equipment has deviated outside acceptable operational limits.

5.2 Centralised control system for machinery

5.2.1 The requirements for a centralised control system for machinery are given in*Pt 6, Ch 1, 5.2 Centralised control station for machinery* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.2.2 In addition to the communication required by *Pt 6, Ch 1, 5.2 Centralised control station for machinery 5.2.5* of the Rules for Ships, a second means of communication is to be provided between the workstation(s) for navigation and manoeuvring and the centralised control station. One of these means is to be independent of the main electrical power supply, *see also Pt 5, Ch 1 General Requirements for the Design and Construction of Machinery*of the Rules for Ships.

■ *Section 6*
Integrated computer control – ICC notation

6.1 General

6.1.1 Integrated Computer Control class notation ICC may be assigned where an integrated computer system in compliance with *Pt 6, Ch 1, 6 Integrated computer control - ICC notation* of the Rules for Ships provides fault tolerant control and monitoring functions for one or more of the following services:

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.

Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.1.2 *Pt 6, Ch 1, 6.1 General 6.1.3* of the Rules for Ships is not applicable to offshore units.

6.2 General requirements

6.2.1 The general requirements for integrated computer control systems are given in *Pt 6, Ch 1, 6.2 General requirements* of the Rules for Ships. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.2.2 The integrated computer control system is to comply with the programmable electronic system requirements of *Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements* to *Pt 6, Ch 1, 2.13 Programmable electronic systems – Additional requirements for integrated systems* and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.3 Alarm and indication functions required by *Pt 6, Ch 1, 2.4 Safety systems* are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also Pt 6, Ch 1, 2.14 Programmable electronic systems – Additional requirements for integrated systems* of the Rules for Ships.

6.2.4 Controls are to be provided, in compliance with *Pt 6, Ch 1, 2.5 Control systems, general requirements*.

6.3 Operator stations

6.3.1 The requirements for the operator stations are given in *Pt 6, Ch 1, 6.3 Operator stations* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.3.2 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g. in control, standby, etc.) is to be clearly indicated, *see also Pt 6, Ch 1, 2.2 Control stations for machinery and equipment*.

■ *Section 7*
Functional testing

7.1 General

7.1.1 The general requirements for the functional tests are given in *Pt 6, Ch 1, 7.1 General* of the Rules for Ships, which are to be complied with.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by *Pt 6, Ch 1, 7.1 General*, the requirements for the functional tests of **UMS** notation during final commissioning sea trials are given in *Pt 6, Ch 1, 7.2 Unattended machinery space operation - UMS notation* of the Rules for Ships, which are to be complied with.

7.3 Operation from a centralised control station – CCS notation

7.3.1 In addition to the tests required by *Pt 6, Ch 1, 7.1 General*, the requirements for the functional tests of **CCS** notation during final commissioning sea trials are given in *Pt 6, Ch 1, 7.3 Operation from a centralised control station - CCS notation* of the Rules for Ships, which are to be complied with.

7.4 Record of trials

7.4.1 The requirements for the records of the trials are given in *Pt 6, Ch 1, 7.4 Record of trials* of the Rules for Ships, which are to be complied with.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all offshore units defined in *Pt 1, Ch 2 Classification Regulations* except where otherwise stated. Where applicable, the relevant requirements for electrical services necessary to maintain the unit in a normal sea-going, operational and habitable condition, for electrical services essential for safety and for the safety of crew and unit from electrical hazards as stated in *Pt 6, Ch 2 Electrical Engineering* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are to be complied with.

1.1.2 Attention is also to be given to any relevant statutory regulation of the National Administration in the country in which the unit is to operate and/or be registered.

1.1.3 Where reference is made to the requirements of the Rules for Ships, references therein to ‘ship(s)’ are to be understood to refer to ‘unit(s)’.

1.2 Documentation required for design review

1.2.1 The documentation in *Pt 6, Ch 2, 1.2 Documentation required for design review* of the Rules for Ships is to be submitted for consideration. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE

Where reference is made in the Rules for Ships to explosive gas atmospheres and/or combustible dusts, or to the electrical equipment for use in those areas, *see also Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres* and *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*.

1.2.2 Electrical system study and calculations are to be in accordance with the IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 9, or an alternative relevant International or National Standard.

1.2.3 The general arrangement of the unit, showing the hazardous zones and spaces, is to include details on the permitted temperature class and gas group of the electrical equipment. The temperature class and apparatus group of the electrical equipment are associated with the ignition temperature and energy required for ignition of the hazardous substances.

1.3 Documentation required for supporting evidence

1.3.1 The documentation and particulars in *Pt 6, Ch 2, 1.3 Documentation required for supporting evidence*of the Rules for Ships are to be submitted as supporting evidence. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.3.2 A description of the philosophy of the systems of power generation and distribution, describing their modes of operation under normal and emergency conditions, is to be submitted.

1.3.3 Arrangement plans of main and emergency switchboards, section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with *Pt 6, Ch 2, 7.5 Creepage and clearance distances*. The form factor of internal separation of low voltage switchgear and control gear assemblies is to be in accordance with IEC 61439-2, *Low-voltage switchgear and control gear assemblies – Part 2: Power switchgear and control gear assemblies*, or alternative relevant International or National Standards. The form factor is to be stated, and the arrangement plans are to show how the form factor has been achieved.

1.4 Surveys

1.4.1 The equipment required to be surveyed is given in *Pt 6, Ch 2, 1.4 Surveys* of the Rules for Ships, which are to be complied with.

1.5 Additions or alterations

1.5.1 The requirements for additions or alterations are given in *Pt 6, Ch 2, 1.5 Additions or alterations* of the Rules for Ships, which are to be complied with.

1.6 Definitions

1.6.1 Definitions are given in *Pt 6, Ch 2, 1.6 Definitions* of the Rules for Ships and in IEC 61892-1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Section 3. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.6.2 Essential services are those necessary for the propulsion and safety of the unit, such as the following:

- Items as given in *Pt 6, Ch 2, 1.6 Definitions 1.6.1* of the Rules for Ships;
- Thruster systems for positional mooring;
- Abandonment systems dependent on electric power;
- Ventilation systems for hazardous areas and those maintained at an overpressure to exclude the ingress of dangerous gases;
- Wellhead control and disconnection systems dependent on electric power.

1.6.3 Services considered necessary for minimum comfortable conditions of habitability are given in *Pt 6, Ch 2, 1.6 Definitions 1.6.2* of the Rules for Ships.

1.6.4 Services such as the following, which are additional to those in *Pt 6, Ch 2, 1.6 Definitions 1.6.2* and *Pt 6, Ch 2, 1.6 Definitions 1.6.3*, are considered necessary to maintain the unit in a normal and sea-going operation and habitable condition:

- Drilling plant equipment;
- Processing and production equipment;
- Hotel services, other than those required for habitable conditions;
- Thrusters, other than those for essential services; and
- Lifting appliances for the transfer of material, equipment or personnel.

1.7 Design and construction of equipment

1.7.1 The requirements for design and construction are given in *Pt 6, Ch 2, 1.7 Design and construction* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.7.2 Equipment or apparatus required to be suitable for use in an explosive gas atmosphere shall comply with the requirements of *Pt 7, Ch 2 Hazardous Areas and Ventilation*, *Pt 6, Ch 2, 8 Protection from electric arc hazards within electrical equipment*, *Pt 6, Ch 2, 9 Rotating machines*, *Pt 6, Ch 2, 10 Converter equipment* and *Pt 6, Ch 2, 11 Electrical cables and busbar trunking systems (busways)*, IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features, IEC 61892-7, Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas* or alternative relevant International or National Standard. Such equipment shall be constructed and tested in accordance with the requirements of the IEC 60079 series, *Explosive atmospheres* (or alternative relevant International or National Standard) and be fit for purpose for the actual ambient temperature and other environmental conditions.

1.8 Quality of power supplies

1.8.1 The requirements for quality of power supplies are given in *Pt 6, Ch 2, 1.8 Quality of power supplies* of the Rules for Ships and IEC 61892- 1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Section 4.7, which are to be complied with.

1.9 Ambient reference and operating conditions

1.9.1 The requirements for ambient reference and operating conditions are given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.9.2 The rating for classification purposes of essential electrical equipment is to be based on the maximum ambient air and water temperatures expected at the location of the unit. In the absence of precise temperatures, the following temperatures are to be assumed:

(a) For units intended to operate within the tropical belt (i.e. between latitudes 35°N and 20°S):

Primary cooling water supply 32°C
Cooling air temperature 45°C.

(b) For units intended to operate in northern or southern waters outside the tropical belt:

Primary cooling water supply 25°C
Cooling air temperature 40°C.

1.9.3 The air temperature range considered with respect to the selection of equipment, the safe operation of which may be subject to limitations on ambient temperature (e.g. safe type electrical equipment), is to be that expected at the location of the equipment, taking into account local sources of heat and the range of ambient air temperature expected at the location of the unit. In the absence of precise information, the maximum air temperature is to be assumed to be that of the cooling air temperature given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* or *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2*, as appropriate, and the minimum is to be assumed to be minus 20°C, or as determined by reference to Annex B of IEC 61892-1, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions.*

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not more than 10°C below that determined by reference to *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* or *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.3*, provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by an independent and redundant cooling unit(s) so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within the cooling temperature (*see Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* and *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2*) until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than the cooling temperature (*see Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* and *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2*); and

- alarms are provided, at a continuously attended control station, to indicate any malfunction of the cooling units. *See also Pt 6, Ch 1, 1.3 Control, alarm and safety equipment 1.3.3*.

1.9.5 Where equipment is to comply with *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.4*, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Items of equipment used for cooling and maintaining the lesser ambient temperature in accordance with *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.4* are considered essential services and are to satisfy the requirements of *Pt 6, Ch 2, 5.2 Essential services*.

1.10 Inclination of the unit

1.10.1 The requirements for inclination of the unit are given in *Pt 6, Ch 2, 1.10 Inclination of ship* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.10.2 Essential and emergency electrical equipment is to operate satisfactorily under the conditions as shown in *Pt 6, Ch 2, 1.10 Inclination of the unit 1.10.2* for column-stabilised, tension-leg and self-elevating units. For buoy and deep draught caisson units, the angles of inclination will be specially considered in each case.

Table 2.1.1 Inclination of other units

Installations,components	Angle of inclination, degrees in any direction			
	Column-stabilised units		Self-elevating units	
	Static	Dynamic	Static	Dynamic
Essential electrical equipment	15	22,5	10	15
Electrical equipment for emergency services	25	25	15	15

1.11 Location and construction of equipment

1.11.1 The requirements for location and construction are given in IEC 61892-1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Sections 4.15 to 4.20 and *Pt 6, Ch 2, 1.11 Location and construction* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.11.2 Electrical equipment, as far as is practicable, is to be located:

(a) Such that it is accessible for the purpose of maintenance and survey;
(b) Clear of flammable material;
(c) In spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*;
(d) Where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to comply with the relevant requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*;
(e) Where it is not exposed to the risk of mechanical injury or damage from water, steam or oil; and
(f) Clear of areas at risk of cryogenic spills.

1.11.3 Equipment located in hazardous areas, or required to remain operational during catastrophic conditions, is to comply with the relevant requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*.

1.11.4 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in *Pt 6, Ch 2, 1.10 Inclination of the unit* for essential electrical equipment, *see also Pt 5, Ch 13 Bilge and Ballast Piping Systems*.

1.11.5 Where electrical equipment is located within areas or adjacent to areas protected by a fixed water-based location application fire-fighting system, they are to comply with *Rules and Regulations for the Classification of Ships, July 2016*,*Pt 6, Ch 2, 17.3 Fixed water-based local application fire-fighting systems*.

1.12 Earthing of non-current-carrying parts

1.12.1 The requirements for earthing of non-current-carrying parts are given in *Pt 6, Ch 2, 1.12 Earthing of non-current carrying parts* of the Rules for Ships and IEC 61892-6:2007 Section 4 *Mobile and fixed offshore units – Electrical installations – Part 6: Installation* which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.12.2 Where the current-carrying conductor exceeds 120 mm^2, a 70 mm^2 earthing conductor is permitted, provided that the circuit protection arrangements are such as will prevent an excessive temperature rise under fault conditions.

1.13 Bonding for the control of static electricity

1.13.1 The requirements for bonding for the control of static electricity are given in *Pt 6, Ch 2, 1.13 Bonding for the control of static electricity* of the Rules for Ships, IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 5.5 and IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation,* Section 4, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.13.2 Bonding straps for the control of static electricity are required for storage tanks, process plant and piping systems located in hazardous areas, or for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the structure of the unit either directly or via their bolted or welded supports and where the resistance between them and the structure exceeds 1MΩ.

1.14 Alarms

1.14.1 The requirements for alarms are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 12.12.2.4 and *Pt 6, Ch 2, 1.14 Alarms* of the Rules for Ships which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.14.2 Cables for emergency alarms and their power sources are to be in accordance with *Pt 6, Ch 2, 1.16 Operation under fire conditions*.

1.14.3 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, cryogenic spill, collision, flooding or similar damage is minimised, *see Pt 6, Ch 2, 1.16 Operation under fire conditions*, *Pt 6, Ch 2, 1.17 Operation under flooding conditions* and *Pt 11, Ch 5, 7 Cryogenic releases*, .

1.15 Labels, signs and notices

1.15.1 The requirements for labels, signs and notices are given in *Pt 6, Ch 2, 1.15 Labels, signs and notices* of the Rules for Ships, which are to be complied with.

1.16 Operation under fire conditions

1.16.1 The requirements for operation under fire conditions are given in *Pt 6, Ch 2, 1.16 Operation under fire conditions* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE

- For fire safety stops, *see also Pt 7, Ch 1, 2.4 Fire safety stops*.
- For low location lighting, *see also Pt 7, Ch 1, 3.5 Escape route or low location lighting (LLL)*.

1.16.2 The following emergency services and their emergency power supplies are also required to be capable of being operated under fire conditions:

- Emergency Shut-down (ESD) systems, *see Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*.
- Emergency Release Systems (ERS), *see Pt 7, Ch 1, 8 Emergency release systems (ERS)*.

1.17 Operation under flooding conditions

1.17.1 The requirements for operation under flooding conditions are given in *Pt 6, Ch 2, 1.17 Operation under flooding conditions* of the Rules for Ships, which are to be complied with.

1.18 Protection of electrical equipment against the effects of lightning strikes

1.18.1 The requirements for protection of electrical equipment against the effects of lightning strikes are given in *Pt 6, Ch 2, 1.18 Protection of electrical equipment against the effects of lightning strikes* of the Rules for Ships, which are to be complied with.

1.19 Programmable electronic systems

1.19.1 The requirements for programmable electronic systems are given in *Pt 6, Ch 2, 1.19 Programmable electronic systems* of the Rules for Ships, which are to be complied with.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to include at least two generating sets and is to comply with the requirements of this Section, *Pt 6, Ch 2, 2 Main source of electrical power* of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 4 without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 The requirements for the number and rating of generators and converting equipment are given in *Pt 6, Ch 2, 2.2 Number and rating of generators and converting equipment* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE

The requirements are applicable when a unit is changing its location (self-propelled or towed) or stationary engaged in its primary function (e.g. drilling, production or lifting, oil storage).

2.2.2 Under normal operating and sea-going conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment, habitable conditions. *See Pt 6, Ch 2, 16.3 Power requirements 16.3.5* of the Rules for Ships for electric propulsion systems;
(b) to have sufficient reserve capacity to permit the starting of the largest motor for essential services without causing any motor to stall or any device to fail due to excessive voltage drop on the system;
(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by*Pt 6, Ch 2, 3 Emergency source of electrical power*, *see also Pt 6, Ch 2, 2.3 Starting arrangements 2.3.2*.

2.2.3 Where the electrical power requirement to maintain the unit in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see Pt 6, Ch 2, 6.9 Load management*. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see Pt 6, Ch 2, 1.6 Definitions 1.6.2*, in as short a time as is practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The requirements for starting arrangements are given in *Pt 6, Ch 2, 2.3 Starting arrangements* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a dead ship condition, the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead ship condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*, *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* and *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*, *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* to *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*. *See Pt 6, Ch 2, 9.1 General requirements 9.1.1* of the Rules for Ships for dead ship condition starting arrangements.

2.4 Prime mover governors

2.4.1 The requirements for prime mover governors are given in *Pt 6, Ch 2, 2.4 Prime mover governors* of the Rules for Ships, which are to be complied with.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 The requirements for generators and generator systems having the unit's propulsion machinery as their prime mover but not forming part of the unit's main source of electrical power are given in *Pt 6, Ch 2, 2.5 Main propulsion driven generators not forming part of the main source of electrical power* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.5.2 In addition to the requirements of *Pt 6, Ch 2, 2.2 Number and rating of generators and converting equipment 2.2.3*, arrangements are to be fitted to start one of the generators forming the main source of power automatically should the frequency variations exceed those permitted by the Rules.

■ *Section 3*
Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to units to be classed for unrestricted service. They do not apply to units of less than 500 tons gross tonnage. Alternative arrangements in accordance with the requirements of the National Administration may also be acceptable.

3.1.2 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the installation is to comply with the requirements of *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power*.

3.1.3 The emergency source of power for units of less than 500 tons gross tonnage will be the subject of special consideration.

3.1.4 For emergency source of electrical power in accommodation units, *see Pt 3, Ch 4, 4.2 Emergency source of electrical power*.

3.2 Emergency source of electrical power

3.2.1 The general requirements for emergency source of electrical power are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, *Pt 6, Ch 2, 4 External source of electrical power* and *Pt 6, Ch 2, 3.4 Emergency source of electrical power in cargo ships* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located in a non-hazardous space above the uppermost continuous deck and above the worst damage waterline, inboard of the damage zones, see *Pt 4, Ch 7, 2 Definitions* and *Pt 4, Ch 7, 3 Installation layout and stability*. They are not to be located forward of the collision bulkhead, if any.

3.2.3 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of hazardous areas or machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.4 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 18 hours, emergency lighting:

- (i) in alleyways, stairways and exits, giving access to the muster and embarkation stations:
- (ii) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift;
- (iii) in the machinery spaces and main generating stations including their control positions;
- (iv) in all control stations, machinery control rooms, and at each main and emergency switchboard;
- (v) at all stowage positions for fireman's outfits;
- (vi) at the steering gear;
- (vii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
- (viii) in any stored oil pump-room;
- (ix) at every survival craft preparation station, muster and embarkation station and over the sides;
- (x) on helicopter decks, to include deck perimeter lights and helideck status lights, wind direction indicator illumination, and related obstruction lights, if any;
- (xi) in all spaces from which control of the drilling process is performed and where controls of machinery essential for the performance of this process, or devices for emergency switching off of the power plant are located; and
- (xii) at ESD manual activation points.

(b) For a period of 18 hours:

- (i) the navigation lights and other lights and sound signals required by the *International Regulations for the Prevention of Collisions at Sea* in force;
- (ii) the radio communications as required by Amendments to *Chapter IV - Radiocommunications*;
- (iii) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
- (iv) the emergency fire pump if dependent upon the emergency generator for its source of power;
- (v) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;
- (vi) on column-stabilised units: ballast pump control system, ballast pump status-indicating system, ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system, heel and trim indicators, power availability indicating system (main and emergency), ballast system hydraulic/pneumatic pressure-indicating sytem and the largest capacity ballast pump required by *Pt 5, Ch 13, 11 Ballast system*of the Rules for Ships; and
- (vii) abandonment systems dependent on electric power.

(c) For a period of 18 hours:

- (i) the navigational aids as required by Amendments to *Regulation 19–1 - Long-range identification and tracking of ships1* as applicable;
- (ii) general alarm and communication systems required in an emergency;
- (iii) intermittent operation of the daylight signalling lamp and the unit's whistle, the manually operated call points and all internal signals that are required in an emergency;
- (iv) the fire and gas detection systems and their alarms; and

(v) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangement, if electrically controlled, unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 18 hours.

(d) The steering gear for the period of time required by *Pt 5, Ch 19, 6 Emergency power* of the Rules for Ships.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures, unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of four days.

(f) For a period of half an hour:

(i) power to operate any watertight doors but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided; and

(ii) power to operate the controls and indicators provided.

(g) Where applicable, the services required by *Pt 6, Ch 2, 2.3 Starting arrangements 2.3.2*.

(h) For a minimum of 30 minutes, the ESD system with its indication circuits as required by *Pt 7, Ch 1, 7.1 General 7.1.10*.

3.2.5 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43°C;

(ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.6* is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.6* are to be connected automatically to the emergency generator; and

(iii) provided with a transitional source of emergency electrical power as specified in *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.6* unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:

(i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.6*.

3.2.6 The transitional source of emergency electrical power where required by *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.5* is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* and *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*, *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*, *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* and *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* and *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.3 Starting arrangements

3.3.1 The requirements for starting arrangements are given in *Pt 6, Ch 2, 3.4 Emergency source of electrical power in cargo ships* of the Rules for Ships, which are to be complied with.

3.4 Prime mover governor

3.4.1 The requirements for prime mover governor are given in *Pt 6, Ch 2, 3.6 Prime mover governor* of the Rules for Ships, which are to be complied with.

3.5 Radio installation

3.5.1 The requirements for radio installation are given in *Pt 6, Ch 2, 3.7 Sources of Energy for Radio installation* of the Rules for Ships, which are to be complied with.

3.6 Accommodation units

3.6.1 The emergency source of electrical power in units carrying more than 50 persons, who are not crew members or passengers, is to comply with the requirements of *Pt 3, Ch 4, 4 Additional requirements for the electrical installation*.

3.7 Alternative sources of emergency electrical power

3.7.1 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the installation is to meet the requirements of this sub-Section.

3.7.2 The main sources of electrical power are to be:

(a) separated and located in two or more compartments that are not contiguous with each other;
(b) self-contained and arranged to be independent such that each system can operate without recourse to the other main source(s) including power distribution and any associated converting equipment and control systems;
(c) arranged such that a fire or casualty in any one of the compartments will not affect the electrical power distribution from the other(s), or to the services required by *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*;

3.7.3 The arrangements in each compartment referred to in *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.2* are to be equivalent to those under paragraphs *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.5* and *Pt 6, Ch 2, 3.4 Emergency source of electrical power in cargo ships 3.4.1* of the Rules of Ships, so that a source of electrical power is available at all times to the services of *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*.

3.7.4 The generator sets forming the main sources of electrical power referred to in *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.2*, are to meet the provision of *Pt 6, Ch 2, 1.10 Inclination of the unit 1.10.2*, with each generator having sufficient capacity to meet the requirements of paragraph *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*, in each of at least two compartments.

3.7.5 The number and arrangements of generators is to allow for maintenance at sea of any one generator without affecting the ability to comply with *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.2*.

3.7.6 Starting arrangements of main sources of electrical power are to comply with the requirements of *Pt 5, Ch 2, 9.4 Starting of the emergency source of power* of the Rules for Ships.

3.7.7 The location of each of the compartments referenced in *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.2* is to comply with *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.2* and the boundaries meet the provisions of *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.3*.

3.7.8 Where these Rules specify that a service is required to be connected to both the main and emergency source of electrical power or is to be connected to the emergency switchboard, these services are to be served by at least two individual circuits from the separated main sources of electrical power with arrangements to transfer between the two sources. The supplies are to be separated in their switchboard and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single electrical fault will not cause the loss of both supplies.

3.7.9 Provision is to be made for periodic testing to demonstrate services required by *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* can be supplied automatically following the loss of one main source of electrical power.

3.7.10 To demonstrate compliance with the requirements of *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.2*, *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.3* and *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.5* a risk assessment is to be carried out demonstrating that a single point failure such as a fire within a space would not render the systems incapable of supplying those services required in an emergency.

Section 4
External source of electrical power

4.1 Temporary external supply

4.1.1 The requirements for temporary external supply are given in *Pt 6, Ch 2, 4.1 Temporary external supply* of the Rules for Ships, which are to be complied with where applicable.

4.2 Permanent external supply

4.2.1 The requirements for permanent external supply are given in *Pt 6, Ch 2, 4.2 Permanent external supply* of the Rules for Ships, which are to be complied with.

Section 5
Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The requirements for systems of supply and distribution are given in *Pt 6, Ch 2, 5.1 Systems of supply and distribution* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.1.2 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire, insulated;
(b) a.c., single-phase, two-wire, insulated;
(c) a.c., three-phase; three-wire, insulated;
(d) earthed systems, a.c. or d.c.

The following neutral earthing methods are permitted:

- Directly earthed TN System.
- Impedance earthed IT System.
- Isolated IT System.

Earthing systems complying with IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 5 and IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 5 are acceptable.

While both insulated and earthed distribution systems (TN-S) are permitted, systems which may result in the presence of electrical currents within the hull or unit structure return (TN-C and TN-C-S) are not permitted, with the exception of:

- limited and locally earthed systems outside any hazardous area;
- intrinsically safe systems;
- impressed current cathodic protection systems.

NOTES

- IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Table 2 summarises the principal features of the neutral earthing methods.
- Systems installed in hazardous areas shall comply with the requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*, *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*, *Pt 7, Ch 2, 10 Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk* and *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes* .
- In hazardous areas (where inflammable gas may be present as defined in IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 4) a.c. systems are to be earthed to comply with IEC 60079-14, *Explosive*

atmospheres – Part 14: Electrical installations design, selection and erection, in particular Section 6 'Protection from dangerous (incentive) sparking', and be arranged so that no current arising from an earth fault in any part of the system could pass through extraneous metalwork located in a hazardous area. Earthed intrinsically safe circuits are permitted to pass into and through hazardous areas.

5.2 Essential services

5.2.1 The requirements for essential services are given in *Pt 6, Ch 2, 5.2 Essential services* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.2.2 Essential services that are required by *Pt 5 MAIN AND AUXILIARY MACHINERY* to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.3 Isolation and switching

5.3.1 The requirements for isolation and switching are given in *Pt 6, Ch 2, 5.3 Isolation and switching* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.3.2 Isolation and switching is to be by means of a circuit-breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short-circuit;

In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see Pt 6, Ch 2, 6.5 Circuit-breakers* and *Pt 6, Ch 2, 7.3 Circuit-breakers*.

5.3.3 Devices selected for isolation of circuits up to and including 1000V a.c or 1500V d.c. shall comply with the relevant International or National Standards.

5.4 Insulated distribution systems (IT systems)

5.4.1 The requirements for insulated distribution systems are given in *Pt 6, Ch 2, 5.4 Insulated distribution systems* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.4.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to monitor continuously the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance and/or high level of leakage current, *see also Pt 6, Ch 1, 4.2 Alarm system for machinery*.

5.4.3 IT systems (neutral isolated from earth or earthed through a high impedance) shall meet the requirements of IEC 61892-2, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features* and IEC 60079-14, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*.

5.5 Earthed distribution systems (TN systems)

5.5.1 The requirements for earthed distribution systems are given in *Pt 6, Ch 2, 5.5 Earthed distribution systems* of the Rules for Ships, which are to be complied with where applicable.

5.5.2 TN systems (directly earthed) shall meet the requirements of IEC 61892-2, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*. TN-C and TN-C-S systems are only permitted for the applications listed in *Pt 6, Ch 2, 5.1 Systems of supply and distribution 5.1.2*.

5.5.3 A device(s) is to be installed for every earthed distribution system, whether primary or secondary, for power, heating and lighting circuits, to monitor continuously the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance and/or high level of leakage current, *see also Pt 6, Ch 1, 4.2 Alarm system for machinery*. This does not apply to the following systems:

- limited and locally earthed systems outside any hazardous area;

- intrinsically safe systems;
- impressed current cathodic protection systems.

5.6 High voltage distribution systems

5.6.1 For systems with nominal voltage 15 kV a.c., or greater, the neutral (star point) shall be earthed by one of the following methods:

(a) High impedance resistor.
(b) Earthing transformer.

The earth fault current should be as low as is reasonably practicable to allow the earth fault protection to operate in a time specified by the protection coordination study and to minimise touch voltages. Systems with resonant earthing (Petersen coil) are not permitted.

5.6.2 Earthing systems serving high voltage systems, including systems with nominal voltage 15 kV a.c. or greater, shall be solidly interconnected with the LV system earthing network to minimise touch voltages. The touch voltages and fault durations shall not exceed the values given in Annex B Touch Voltage and Body Current of BS EN 50522:2012, *Earthing of power installations exceeding 1 kV a.c*.

NOTE

Although offshore units are outside the scope of BS EN 50522, earthing of power installations exceeding 1 kV a.c. guidance on dangerous touch voltages and earthing system design may be obtained from this standard.

5.7 Diversity factor

5.7.1 The requirements for the diversity factor are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 8 and *Pt 6, Ch 2, 5.6 Diversity factor* of the Rules for Ships, which are to be complied with.

5.8 Lighting circuits

5.8.1 The requirements for lighting circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 11 and *Pt 6, Ch 2, 5.7 Lighting circuits* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.8.2 Escape lighting fittings supplied by a central battery system or UPS are to be connected to the power source using fire-resistant cables and comply with the relevant International or National Standards.

5.8.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised, in which case the arrangements are to comply with *Pt 6, Ch 2, 3 Emergency source of electrical power*.

5.8.4 Emergency lighting is to be fitted in accordance with *Pt 6, Ch 2, 3 Emergency source of electrical power*, *see also Pt 7, Ch 1, 4 Emergency lighting*.

5.8.5 Where lighting circuits in a stored oil pump-room adjacent to a storage tank are also used for emergency lighting, and have been interlocked with ventilation, the interlocking arrangements are:

- not to cause the lighting to go out following a failure of the ventilation system; and
- not to prevent operation of the emergency lighting following the loss of the main source of electrical power.

5.9 Motor circuits

5.9.1 A separate final sub-circuit is to be provided for every motor for essential services, *see Pt 6, Ch 2, 1.6 Definitions 1.6.2*.

5.10 Motor control

5.10.1 The requirements for motor control are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 7.8 and *Pt 6, Ch 2, 5.9 Motor control* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.10.2 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also Pt 6, Ch 2, 6.10 Feeder circuits*.

■ *Section 6*
System design – Protection

6.1 General

6.1.1 The general requirements for protection are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10 and *Pt 6, Ch 2, 6.1 General* of the Rules for Ships, which are to be complied with.

6.2 Protection against short-circuit

6.2.1 The general requirements for protection against short-circuit are given in *Pt 6, Ch 2, 6.2 Protection against short-circuit* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit-breakers and fuses are detailed in *Pt 6, Ch 2, 6.5 Circuit-breakers* and *Pt 6, Ch 2, 6.6 Fuses* respectively.

6.3 Protection against overload

6.3.1 The general requirements for protection against overload are given in *Pt 6, Ch 2, 6.3 Protection against overload* of the Rules for Ships, which are to be complied with.

6.4 Protection against earth faults

6.4.1 The general requirements for protection against short-circuit are given in *Pt 6, Ch 2, 6.4 Protection against earth faults* of the Rules for Ships, which are to be complied with. For systems of 15 kV a.c. and above, *see also Pt 6, Ch 2, 5.6 High voltage distribution systems*. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.4.2 Where any circuit, other than an intrinsically safe circuit, passes into or through any Zone 0 area, the circuit is to be disconnected automatically and/or is to be prevented from being energised in the event of an abnormally low level of insulation resistance and/or high level of leakage current.

6.4.3 Where a circuit passes into any zone 0 area, the protective systems shall be arranged so that manual intervention is necessary for the reconnection of the circuit after disconnection as the result of a short-circuit, overload or earth-fault condition.

6.5 Circuit-breakers

6.5.1 The requirements for circuit-breakers are given in *Pt 6, Ch 2, 6.5 Circuit-breakers* of the Rules for Ships, which are to be complied with.

6.6 Fuses

6.6.1 The requirements for fuses are given in *Pt 6, Ch 2, 6.6 Fuses* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.6.2 The use of fuses for overload protection is permitted up to 320A, provided they have suitable characteristics, but the use of circuit-breakers or similar devices is recommended above 200A. For high voltage a.c. systems (above 1 kV a.c.), the use of fuses for overload protection is not acceptable.

Is Limiters

The use of Is Limiters is permitted in situations where circuit-breakers cannot provide any protection against unduly high peak short-circuit currents, as circuit-breakers are too slow.

NOTE

Only the Is Limiter is capable of detecting and limiting a short-circuit current at the first rise, i.e. in less than 1 ms. The maximum instantaneous current occurring remains well below the level of the peak short-circuit current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The requirements for circuit-breakers requiring back-up by fuse or other devices are given in *Pt 6, Ch 2, 6.7 Circuit-breakers requiring back-up by fuse or other device* of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations –- Part 2: System design*, Section 10.2.3, which are to be complied with.

6.8 Protection of generators

6.8.1 The requirements for the protection of generators are given in *Pt 6, Ch 2, 6.8 Protection of generators* of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.2, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with *Pt 6, Ch 2, 5.3 Isolation and switching 5.3.2*, in each insulated pole will be acceptable.

6.8.3 Where generators are intended to operate in parallel:

(a) Generators are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit-breaker, will instantaneously open the circuit-breaker and de-excite the generator.
(b) Under-voltage protection shall be provided to prevent the generator circuit-breaker from closing if the generator is not generating, in accordance with Section 10.5.1 of IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*.

6.9 Load management

6.9.1 The requirements for load management are given in IEC 61892-5:2010, *Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units*, Section 9.9.2, IEC 60092-504, *Electrical installations in ships – Part 504: Special features – Control and instrumentation* and *Pt 6, Ch 2, 6.9 Load management* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.9.2 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded, sufficient to ensure the connected generating set(s) is/are not overloaded:

- non-essential circuits;
- circuits feeding services for habitability, *see Pt 6, Ch 2, 1.6 Definitions 1.6.2* of the Rules for Ships; and
- circuits for other essential services, when it can be established that safe operation can be maintained during the temporary loss of such services.

6.10 Feeder circuits

6.10.1 The requirements for feeder circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.5 and *Pt 6, Ch 2, 6.10 Feeder circuits* of the Rules for Ships, which are to be complied with.

6.11 Motor circuits

6.11.1 The requirements for motor circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.6 and *Pt 6, Ch 2, 6.11 Motor circuits* of the Rules for Ships, which are to be complied with.

6.12 Protection of transformers

6.12.1 The requirements for protection of transformers are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.4 and *Pt 6, Ch 2, 6.12 Protection of transformers* of the Rules for Ships, which are to be complied with where applicable.

6.13 Harmonic filters

6.13.1 The requirements for protection of transformers are given in *Pt 6, Ch 2, 6.13 Harmonic filters* of the Rules for Ships, which are to be complied with.

Section 7
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 The general requirements for switchgear and control gear assemblies and their components are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 7 and *Pt 6, Ch 2, 7.1 General requirements* of the Rules for Ships, which are to be complied with where applicable. Special consideration shall be given for voltages above 35 kV a.c. and 1,5 kV d.c., Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.1.2 Switchgear and control gear assemblies and their components are to comply with one of the following Standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439, *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 62271-201, *High voltage switchgear and control gear – Part 201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV*;
(d) IEC 60255, *Electrical Relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests*;
(e) IEC 62271-205, *High-voltage switchgear and controlgear – Part 205: Compact switchgear assemblies for rated voltages above 52 kV*;
(f) IEC 62271-203, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52kV*;
(g) alternative relevant International or National Standards. In addition, the requirements of this Section are to be complied with.

7.2 Busbars

7.2.1 The requirements for busbars and their connections are given in *Pt 6, Ch 2, 7.2 Busbars* of the Rules for Ships, which are to be complied with where applicable.

7.3 Circuit-breakers

7.3.1 The requirements for circuit-breakers are given in *Pt 6, Ch 2, 7.3 Circuit-breakers* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.3.2 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2, *Low voltage switchgear and Control gear – Part 2: Circuit-breakers*;
(b) IEC 62271-100, *High-voltage switchgear and control gear – Part 100: High-voltage alternating-current circuit-breakers*;
(c) IEC 62271-108, *High-voltage switchgear and controlgear – Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72,5 kV and above*.
(d) Alternative relevant International or National Standards. Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.4 Contactors

7.4.1 The requirements for contactors are given in *Pt 6, Ch 2, 7.4 Contactors* of the Rules for Ships, which are to be complied with where applicable.

7.5 Creepage and clearance distances

7.5.1 The requirements for creepage and clearance distances are given in *Pt 6, Ch 2, 7.5 Creepage and clearance distances* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.5.2 For assemblies with a rated voltage of up to and including 1kV, the requirement of *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.1* may met by complying with IEC 60092-302, *Electrical installations in ships – Part 302: Low-voltage switchgear and controlgear assemblies*.

- *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.1* and *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.3* in *Pt 6, Ch 2, 7.5 Creepage and clearance distances* of the Rules of Ships indicate the minimum clearance and creepage distances normally allowed.
- For assemblies installed in spaces where the environmental conditions are in excess of pollution degree 3 (that is conductive pollution occurs or dry, non conductive pollution occurs which is expected to be conductive due to condensation) as defined in IEC 61439-1, *Low voltage switchgear and controlgear assemblies – Part 1: General rules; the clearance distances for non-verified assemblies are to be used*.
- A minimum creepage distance of 16 mm is permitted for assemblies verified in accordance with the requirements of IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*.
- An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Pt 6, Ch 2, 1.3 Documentation required for supporting evidence 1.3.3*.

7.5.3 For assemblies with a rated voltage above 1kV, the requirement of*Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.1* of the Rules of Ships may be met by complying with IEC 60092-503, *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*.

- *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.1* and *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.3* in *Pt 6, Ch 2, 7.5 Creepage and clearance distances*of the Rules of Ships indicate the minimum clearance and creepage distances normally allowed.
- For main switchboards rated at above 1kV, a minimum clearance distance of 25 mm is required for busbars and other bare conductors.

An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Pt 6, Ch 2, 1.3 Documentation required for supporting evidence 1.3.3*.

For voltage levels above 15 kV a.c., creepage distances are to comply with manufacturer's recommendations and alternative relevant International or National Standards.

7.5.4 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in *Pt 6, Ch 2, 7.5 Creepage and clearance distances 7.5.1* in *Pt 6, Ch 2, 7.5 Creepage and clearance distances* of the Rules for Ships. Suitable bushing is to be provided in way of connections to equipment, where necessary, to comply with IEC 60137, *Insulated bushings for alternating voltages above 1 000 V*.

7.6 Degree of protection

7.6.1 The requirements for the degree of protection are given in *Pt 6, Ch 2, 7.6 Degree of protection* of the Rules for Ships, which are to be complied with where applicable.

7.7 Distribution boards

7.7.1 The requirements for the distribution boards are given in *Pt 6, Ch 2, 7.7 Distribution boards* of the Rules for Ships, which are to be complied with where applicable.

7.8 Earthing of high-voltage switchboards

7.8.1 The requirements for earthing of high-voltage switchboards are given in *Pt 6, Ch 2, 7.8 Earthing of high-voltage switchboards* of the Rules for Ships, which are to be complied with where applicable.

7.9 Fuses

7.9.1 The requirements for fuses are given in *Pt 6, Ch 2, 7.9 Fuses* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.9.2 Fuses are to comply with one of the following Standards amended where necessary for ambient temperature:

(a) IEC 60269, *Low-voltage fuses*;
(b) IEC 60282-1, *High voltage fuses – Part 1: Current-limiting fuses*;
(c) IEC 60282-2, *High-voltage fuses – Part 2: Expulsion fuses*;
(d) Alternative relevant International or National Standards for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrails or handles

7.10.1 The requirements for handrails or handles are given in *Pt 6, Ch 2, 7.10 Handrails or handles* of the Rules for Ships, which are to be complied with where applicable.

7.11 Instruments for alternating current generators

7.11.1 The requirements for instruments of the alternating current generators are given in *Pt 6, Ch 2, 7.11 Instruments for alternating current generators* of the Rules for Ships, which are to be complied with where applicable.

7.12 Instrument scales

7.12.1 The requirements for instrument scales are given in *Pt 6, Ch 2, 7.12 Instrument scales* of the Rules for Ships, which are to be complied with where applicable.

7.13 Labels

7.13.1 The requirements for labels are given in *Pt 6, Ch 2, 7.13 Labels* of the Rules for Ships, which are to be complied with where applicable.

7.14 Protection

7.14.1 The requirements for protection are given in *Pt 6, Ch 2, 6 System design – Protection*, which are to be complied with.

7.15 Wiring

7.15.1 The requirements for wiring are given in *Pt 6, Ch 2, 7.15 Wiring* of the Rules for Ships, which are to be complied with where applicable.

7.16 Position of switchboards

7.16.1 The requirements for position of switchboards are given in *Pt 6, Ch 2, 7.16 Position of switchboards* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.16.2 When switchboards and section boards contain withdrawable equipment, an unobstructed space as defined by the manufacturer but not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position. Adequate space for operation and maintenance is to be provided around and above the switchboards and section boards.

7.16.3 So far as possible, pipes should not be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see Pt 5, Ch 13, 2 Construction and installation* of the Rules for Ships and *Pt 5, Ch 13, 2 Construction and installation*.

7.16.4 For switchgear and controlgear assemblies, for rated voltages above 1 kV a.c., arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*or Annex B of IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV* and qualified for classification IAC (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 The requirements for switchboard auxiliary power supplies are given in *Pt 6, Ch 2, 7.17 Switchboard auxiliary power supplies* of the Rules for Ships, which are to be complied with where applicable.

7.18 Testing

7.18.1 The requirements for testing are given in *Pt 6, Ch 2, 7.18 Testing* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.18.2 For switchgear and control gear assemblies, for rated voltages above 1 kV a.c., type tests are to be carried out in accordance with Annex A of IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* or Annex B of IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV* and IAC (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 The requirements for testing are given in *Pt 6, Ch 2, 7.19 Disconnectors and switch-disconnectors* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.19.2 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3, *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*;
(b) IEC 62271-102, *High-voltage switchgear and control gear – Part 102: High-voltage alternating current disconnectors and earthing switches*;
(c) IEC 62271-104, *High-voltage switchgear and control gear – Part 104: Alternating current switches for rated voltages of 52 kv and above*;
(d) Alternative relevant International or National Standards. Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8*
Protection from electric arc hazards within electrical equipment

8.1 Hazard identification, calculations and testing

8.1.1 The requirements for protection from electric arc hazards within electrical equipment are given in *Pt 6, Ch 2, 8 Protection from electric arc hazards within electrical equipment* of the Rules for Ships, which are to be complied with.

■ *Section 9*
Rotating machines

9.1 Construction, performance, control and testing

9.1.1 The requirements for construction, performance, control and testing of rotating machines are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 5 and *Pt 6, Ch 2, 9 Rotating machines* of the Rules for Ships, which are to be complied with.

9.1.2 Additions or amendments to these requirements are given in *Pt 6, Ch 2, 9.2 Temperature rise*.

9.2 Temperature rise

9.2.1 The limits of temperature rise specified in *Pt 6, Ch 2, 9.4 Generator control 9.4.3* in *Pt 6, Ch 2, 9.3 Temperature rise* of the Rules for Ships are based on the cooling air temperature and cooling water temperature given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2*.

9.2.2 If it is known that the temperature of cooling medium exceeds the values given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.2.3 If it is known that the temperature of cooling medium will be permanently less than the values given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2* the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions 1.9.2*, up to a maximum of 15°C.

■ *Section 10*
Converter equipment

10.1 Transformers

10.1.1 The requirements for transformers are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 6 and *Pt 6, Ch 2, 10.1 Transformers* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.1.2 Transformers are to comply with the requirements of IEC Publications 60076, *Power transformers*, or alternative relevant International or National Standards amended where necessary for ambient temperature, *see Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*.

10.2 Semi-conductor converters

10.2.1 The requirements for semi-conductor converters are given in IEC 61892-3:2013, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 8 and *Pt 6, Ch 2, 10.2 Semiconductor converters* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.2.2 Semi-conductor converters are to comply with the requirements of IEC 60146: *Semi-conductor Converters*, or alternative relevant International or National Standards amended where necessary for ambient temperature, *see Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*.

10.3 Uninterruptible power systems (UPS)

10.3.1 The requirements for uninterruptible power systems are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Sections 8 and 9, and *Pt 6, Ch 2, 10.3 Uninterruptible power systems* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.3.2 UPS units are to comply with the requirements of IEC 62040, *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*, or alternative relevant International or National Standard amended where necessary for ambient temperature, *see Pt 6, Ch 2, 1.9 Ambient reference and operating conditions*.

10.3.3 A.C. Uninterruptable Power Systems (UPSs) shall have isolated neutrals or TN-S, *see Pt 6, Ch 2, 5.1 Systems of supply and distribution*.

10.3.4 An external bypass, that is hardwired and manually operated, is to be provided to the UPS system, to allow for isolation of the UPS for safety during maintenance and maintain continuity of load power. When the UPS is operating in either normal or by-pass mode it must be ensured that there are no multiple system earths.

■ Section 11
Electrical cables and busbar trunking systems (busways)

11.1 General

11.1.1 The general requirements of electrical cables, optical fibre cables and busbar trunking systems (busways) are given in *Pt 6, Ch 2, 11.1 General* of the Rules for Ships and IEC 61892-4 (all parts), *Mobile and fixed offshore units – Electrical installations – Part 4: Cables*, which are to be complied with where applicable

11.2 Testing

11.2.1 The requirements for testing are given in *Pt 6, Ch 2, 11.2 Testing* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.2.2 For cables with rated voltage above 30 kV a.c. guidance for requirements and test methods can be obtained from IEC 60840, *Power Cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements*.

11.3 Voltage rating

11.3.1 The requirements for voltage rating are given in *Pt 6, Ch 2, 11.3 Voltage rating* of the Rules for Ships, which are to be complied with where applicable.

11.4 Operating temperature

11.4.1 The requirements for operating temperature are given in *Pt 6, Ch 2, 11.4 Operating temperature* of the Rules for Ships, which are to be complied with where applicable.

11.5 Construction

11.5.1 The requirements for construction are given in *Pt 6, Ch 2, 11.5 Construction* of the Rules for Ships, which are to be complied with where applicable.

11.6 Conductor size

11.6.1 The requirements for conductor sizing are given in *Pt 6, Ch 2, 11.6 Conductor size* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.6.2 The cable current ratings given in *Pt 6, Ch 2, 11.6 Conductor size 11.6.5* and *Pt 6, Ch 2, 11.6 Conductor size 11.6.5* in *Pt 6, Ch 2, 11.6 Conductor size* of the Rules for Ships are based on the maximum rated conductor temperatures given in *Pt 6, Ch 2, 11.4 Operating temperature 11.4.2* in *Pt 6, Ch 2, 11.4 Operating temperature*of the Rules for Ships. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table *Pt 6, Ch 2, 11.6 Conductor size 11.6.5*, may be applied using the data provided in:

- IEC 60724, *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986, *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.
- IEC 61443, *Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um = 36 kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

11.7 Correction factor for cable current rating

11.7.1 The requirements for the correction factor for cable current rating are given in *Pt 6, Ch 2, 11.7 Correction factors for cable current rating* of the Rules for Ships, which are to be complied with where applicable.

11.8 Installation of cables

11.8.1 The requirements for installation of cables are given in *Pt 6, Ch 2, 11.8 Installation of electric cables* of the Rules for Ships and IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 5, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.8.2 The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in *Pt 6, Ch 2, 11.8 Installation of electric cables 11.8.6* in *Pt 6, Ch 2, 11.8 Installation of electric cables* of the Rules for Ships. Bends in fixed electric cable runs are only to be in accordance with the cable manufacturer's recommendations if the recommended bending radii are greater than the values given in *Pt 6, Ch 2, 11.8 Installation of electric cables 11.8.6* in *Pt 6, Ch 2, 11.8 Installation of electric cables*of the Rules for Ships.

11.8.3 All cables as far as is practicable are to be located outside areas at risk of cryogenic spill.

11.9 Mechanical protection of cables

11.9.1 The requirements for mechanical protection of cables are given in *Pt 6, Ch 2, 11.9 Mechanical protection of cables* of the Rules for Ships, which are to be complied with where applicable.

11.10 Cable support system

11.10.1 The requirements for the cable support system are given in *Pt 6, Ch 2, 11.10 Cable support systems* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.10.2 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in *Pt 6, Ch 2, 11.10 Cable support systems 11.10.3* in *Pt 6, Ch 2, 11.10 Cable support systems* of the Rules for Ships or manufacturer's recommendations, whichever requires a smaller distance between supports.

11.11 Penetration of bulkheads and decks by cables

11.11.1 The requirements for penetrations of bulkheads and decks by cables are given in *Pt 6, Ch 2, 11.11 Penetration of bulkheads and decks by cables* of the Rules for Ships, which are to be complied with where applicable.

11.12 Installation of electric and optical fibre cables in protective casings

11.12.1 The requirements for installation of electric and optical fibre cables in protective casings are given in *Pt 6, Ch 2, 11.12 Installation of electric and optical fibre cables in protective casings* of the Rules for Ships, which are to be complied with where applicable.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 The requirements for non-metallic cable support systems, protective casings and fixings are given in *Pt 6, Ch 2, 11.13 Non-metallic cable support systems, protective casings and fixings* of the Rules for Ships, which are to be complied with where applicable.

11.14 Single-core electric cables for alternating current

11.14.1 The requirements for single-core electric cables for alternating current are given in*Pt 6, Ch 2, 11.14 Single-core electric cables for alternating current* of the Rules for Ships, which are to be complied with where applicable.

11.15 Electric cable ends

11.15.1 The requirements for electric cable ends are given in *Pt 6, Ch 2, 11.15 Electric cable ends* of the Rules for Ships, which are to be complied with where applicable.

11.16 Joint and branch circuits in cable systems

11.16.1 The requirements for joint and branch circuits in cable systems are given in *Pt 6, Ch 2, 11.16 Joints and branch circuits in cable systems* of the Rules for Ships, which are to be complied with where applicable.

11.17 Busbar trunking systems (bustrunks)

11.17.1 The requirements for busbar trunking systems (bustrunks) are given in *Pt 6, Ch 2, 11.17 Busbar trunking systems (bustrunks)* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.17.2 Where the busbar trunking system is employed for circuits on and below the freeboard deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in *Pt 6, Ch 2, 1.10 Inclination of the unit* for essential electrical equipment.

■ *Section 12* **Batteries**

12.1 General

12.1.1 The requirements for batteries of the vented and valve regulated sealed type are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 9 and *Pt 6, Ch 2, 12.1 General* of the Rules for Ships, which are to be complied with where applicable.

12.2 Construction

12.2.1 The requirements for construction are given in *Pt 6, Ch 2, 12.2 Construction* of the Rules for Ships, which are to be complied with where applicable.

12.3 Location

12.3.1 The requirements for construction are given in *Pt 6, Ch 2, 12.3 Location* of the Rules for Ships, which are to be complied with where applicable.

12.4 Installation

12.4.1 The requirements for installation are given in *Pt 6, Ch 2, 12.4 Installation* of the Rules for Ships, which are to be complied with where applicable.

12.5 Ventilation

12.5.1 The requirements for ventilation are given in *Pt 6, Ch 2, 12.5 Ventilation* of the Rules for Ships, which are to be complied with where applicable.

12.6 Charging facilities

12.6.1 The requirements for charging facilities are given in *Pt 6, Ch 2, 12.6 Charging facilities* of the Rules for Ships, which are to be complied with where applicable.

12.7 Recording of batteries for emergency and essential services

12.7.1 The requirements for recording batteries are given in *Pt 6, Ch 2, 12.7 Recording of batteries for emergency and essential services* of the Rules for Ships, which are to be complied with where applicable.

■ *Section 13*
Equipment – Heating, lighting and accessories, electric trace heating and underwater systems

13.1 Heating and cooking equipment, lighting, socket outlets and plugs and enclosures

13.1.1 The requirements for heating and cooking equipment, lighting, socket outlets and plugs, and equipment enclosures are given in IEC 61892-3, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment* and *Pt 6, Ch 2, 13 Equipment - Heating, lighting and accessories* of the Rules for Ships, which are to be complied with.

13.2 Electric trace heating

13.2.1 Electric trace heating shall comply with IEC 61892- 3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 12 trace heating installations in hazardous areas shall comply with IEC 60079, *Explosive atmospheres – Part 0: Equipment – General requirements* series or a relevant International or National Standard.

13.3 Underwater systems/impressed current cathodic protection

13.3.1 Underwater systems and appliances are to comply with IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 14. To facilitate diving operations provision is to be made to isolate Impressed Current Cathodic Protection Systems.

■ *Section 14*
Refrigeration

14.1 General

14.1.1 Refrigeration required in units to facilitate LNG production and/or cryogenic storage is to comply with the requirements of IEC 60092-502, *Electrical installations in ships – Tankers – Special features*. Control and instrumentation associated with refrigeration systems is to comply with IEC 60092-504, *Electrical installation in ships – Special features – Control and Instrumentation.*

14.1.2 For LR approval of LNG refrigeration/reliquefaction system, the plant is to be considered as a self-contained essential system. Therefore, approval procedures will be performed for the complete plant as well as the major items of equipment.

14.1.3 Electrical, control and instrumentation equipment is to be suitable for its intended purpose and accordingly, whenever practicable, is to be selected from the List of Type Products published by LR. A copy of the procedure for LR Type Approval System will be supplied on application.

■ *Section 15*
Navigation and manoeuvring systems

15.1 Steering gear

15.1.1 The requirements for steering gear are given in *Pt 6, Ch 2, 15.1 Steering gear* of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.1.2 These requirements are to be read in conjunction with those in *Pt 5, Ch 19 Steering Gear*.

15.1.3 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

15.2 Thruster systems for steering

15.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven, the requirements of *Pt 5, Ch 20, 5 Electrical equipment* of the Rules for Ships are to be complied with.

15.3 Thruster systems for dynamic positioning

15.3.1 For units having a **DP** class notation the requirements of *Pt 3, Ch 9 Dynamic Positioning Systems* are to be complied with.

15.4 Thruster systems for manoeuvring

15.4.1 Where a thruster system is fitted solely for the purpose of manoeuvring and is electrically driven, the requirements of *Pt 6, Ch 2, 15.4 Thruster systems for manoeuvring* of the Rules for Ships are to be complied with.

15.5 Transverse thrust units

15.5.1 Where transverse units are remotely controlled, the requirements of *Pt 6, Ch 2, 15.5 Transverse thrust units* of the Rules for Ships are to be complied with.

15.6 Thruster systems for thruster-assisted mooring systems

15.6.1 For units having a thruster-assisted positional mooring system the requirements of *Pt 3, Ch 10 Positional Mooring Systems* are to be complied with.

15.7 Navigation lights and sound signals

15.7.1 The requirements for navigation lights are given in IEC 61892-5:2010, *Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units*, Section 7 and *Pt 6, Ch 2, 15.6 Navigation lights* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.7.2 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and accessible to the Officer of the Watch. The distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4* and *Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.5*. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*. An alarm is to be activated in the event of failure of a power supply from the distribution board. Disconnectable units are permitted for this purpose, i.e. for when the unit is not stationary and engaged in operations.

15.7.3 Signalling lights or sound signals required for marking offshore structures are to be fed from an emergency source of electrical power, *see Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*.

15.7.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

15.8 Navigational aids

15.8.1 Navigational aids as required by SOLAS are to be fed from the emergency source of electrical power, *see also Pt 6, Ch 2, 3.4 Emergency source of electrical power in cargo ships 3.4.1* of the Rules for Ships, which are to be complied with. Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.8.2 When a unit is stationary and engaged in operations, navigation aids (lanterns and sound signals) shall be provided in accordance with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) requirements and the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

15.9 Helideck and aircraft warning lights

15.9.1 Helideck perimeter lighting, helideck floodlights, aircraft warning lights, status (wave-off) lights and unit identification signage are to comply with UK Standard CAP 437, *Standards for Offshore Helicopter Landing Areas* or the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

15.9.2 Helideck perimeter lighting, helideck floodlights, aircraft warning lights and status lights are to be supplied by a UPS backed supply. The UPS autonomy is to be agreed with LR and the unit Owner and be in accordance with the requirements of any relevant Statutory Regulations of the National Administrations in the country of registration and area of operation.

15.9.3 Signalling lights or sound signals required for marking offshore structures are to be fed from an emergency source of electrical power, *see Pt 6, Ch 2, 3.2 Emergency source of electrical power 3.2.4*.

15.9.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

■ *Section 16*
Electric propulsion

16.1 General

16.1.1 The requirements for electric propulsion are given in *Pt 6, Ch 2, 16 Electric propulsion* of the Rules for Ships, which are to be complied with. This Section applies to disconnectable self-propelled units or units which use their thrusters to stay on-station or to move off-station (e.g. in adverse weather conditions). Thruster systems fitted for the purpose of manoeuvring or steering are to comply with *Pt 6, Ch 2, 15 Navigation and manoeuvring systems*.

■ *Section 17*
Testing and trials

17.1 Testing

17.1.1 The requirements for testing are given in *Pt 6, Ch 2, 21.1 Testing* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.1.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR and is to be based on approved test schedules.

NOTES

(a) For high voltage cables up to 36 kV a.c., high voltage testing may be carried out in accordance with IEC 60502 (all parts), *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)*.

(b) For high voltage cables up to 69 kV a.c., high voltage testing may be carried out in accordance with IEEE Std. 400.2, *IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)*.

17.1.3 Minimum values of test voltage and insulation resistance are given in *Pt 6, Ch 2, 17.1 Testing 17.1.3*, as per IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 17.3.

Table 2.17.1 Test voltage and minimum insulation

Rated voltage U_{n} V	Minimum voltageof the tests, V	Minimum insulationresistance, MΩ
$U_{\text{n}} \leq 400$	500	1
$400 < U_{\text{n}} \leq 500$	500	$\frac{U_{\text{n}}}{1000} + 1$
$500 < U_{\text{n}} \leq 1000$	1000	$\frac{U_{\text{n}}}{1000} + 1$

$1000 < U_n \leq 6000$	2500	$\frac{U_n}{1000} + 1$
$6000 < U$	5000	$\frac{U_n}{1000} + 1$

17.1.4 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed. It is to be ensured that the test voltage is above the operation voltage.

17.2 Trials

17.2.1 The requirements for trials are given in *Pt 6, Ch 2, 21.2 Trials* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.2.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR and is to be based on approved test schedules.

17.2.3 Minimum values of test voltage and insulation resistance are given in *Pt 6, Ch 2, 17.1 Testing 17.1.3*, as per IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 17.3.

17.3 High voltage cables

17.3.1 The requirements for high voltage cables are given in *Pt 6, Ch 2, 21.3 High voltage cables* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.3.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR.

17.4 Hazardous areas

17.4.1 The requirements for testing of electrical equipment located in hazardous areas are given in *Pt 6, Ch 2, 21.4 Hazardous areas* of the Rules for Ships, which are to be complied with where applicable.

NOTE

For hazardous areas, *see Pt 7, Ch 2 Hazardous Areas and Ventilation*.

■ *Section 18*
Spare gear

18.1 General

18.1.1 The general requirements for spare gear are given in *Pt 6, Ch 2, 22.1 General* of the Rules for Ships, which are to be complied with where applicable.

Section 1
Codes and Standards

1.1 Abbreviations

1.1.1 The following abbreviations are used in this Appendix:

CAP. Civil Aviation Publication

IEC. International Electrotechnical Commission

IEEE. Institute of Electrical and Electronics Engineers

1.2 Recognised Codes and Standards

1.2.1 The following Codes and Standards are recognised by LR in connection with the design, construction and installation of equipment and systems which form part of the control and electrical systems installed on offshore units as appropriate.

1.2.2 The following National and International Codes and Standards listed are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

1.2.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR.

1.2.4 Control and electrical systems:

CAP 437. Standards for Offshore Helicopter Landing Areas

IEC 60076. Power transformers

IEC 60079. Explosive atmospheres

IEC 60092-302. Electrical installations in ships — Part 302: Low-voltage switchgear and controlgear assemblies

IEC 60092-502. Electrical installations in ships — Part 502: Tankers — Special features

IEC 60092-503. Electrical installations in ships — Part 503: Special features — AC supply systems with voltages in the range of above 1 kV up to and including 15 kV

IEC 60092-504. Electrical installations in ships — Part 504: Special features — Control and instrumentation

IEC 60137. Insulated bushings for alternating voltages above 1 000 V

IEC 60146. Semiconductor converters — General requirements and line commutated converters

IEC 60255. Electrical Relays

IEC 60269. Low-voltage fuses

IEC 60282. High-voltage fuses

IEC 60502. Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)

IEC 60724. Short-circuit temperature limits of electric cables with rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)

IEC 60840. Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) — Test methods and requirements

IEC 60947. Low-voltage switchgear and controlgear

IEC 60986. Short-circuit temperature limits of electric cables with rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)

IEC 61439. Low-voltage switchgear and controlgear assemblies

IEC 61443. Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um = 36 kV)

IEC 61508. Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61892. Mobile and fixed offshore units — Electrical installations

IEC 62040. Uninterruptible power systems (UPS)

IEC 62271-100. High-voltage switchgear and controlgear —Part 100: Alternating current circuit-breakers

IEC 62271-102. High-voltage switchgear and controlgear —Part 102: Alternating current disconnectors and earthing switches

IEC 62271-104. High-voltage switchgear and controlgear —Part 104: Alternating current switches for rated voltages of 52 kV and above

IEC 62271-108. High-voltage switchgear and controlgear — Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72,5 kV and above

IEC 62271-200. High-voltage switchgear and controlgear — Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

IEC 62271-201. High-voltage switchgear and controlgear —Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

IEC 62271-203. High-voltage switchgear and controlgear —Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV

IEC 62271-205. High-voltage switchgear and controlgear — Part 205: Compact switchgear assemblies for rated voltages above 52 kV

IEEE Std. 400.2. IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

Contents

■ *Section 1*
General requirements

1.1 General

1.1.1 This Chapter applies to all units defined in *Pt 1, Ch 2 Classification Regulations* on board which drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk is undertaken. It is also applicable to Accommodation Units and Support Units as detailed in *Pt 3, Ch 4 Accommodation and Support Units*. However, Accommodation Units and Support Units not engaged in activities with drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk units need not comply with all the requirements of *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems*, in relation to gas detection, or the requirements of *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas*, *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas*, *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* or *Pt 7, Ch 1, 8 Emergency release systems (ERS)*of this Chapter. This Chapter also states the fire detection requirements for units to be assigned the **UMS** and **CCS** notations, *see Pt 6, Ch 1, 4 Unattended machinery space(s) – UMS notation* and *Pt 6, Ch 1, 5 Machinery operated from a centralised control station – CCS notation*. Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and area of operation, as applicable.

1.1.2 While *Pt 7, Ch 2 Hazardous Areas and Ventilation*prescribes the boundaries of hazardous areas where special precautions are to be applied, the safeguards called for in this Chapter include provision for actions applicable where gas is present beyond hazardous area boundaries. Such circumstances may arise, for example, as the consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 These requirements apply to manned units. Special consideration will be given to unmanned units which are controlled from the shore or from another unit. When accommodation and support units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production units, it is the responsibility of the Owner/Operator to comply with the requirements of the appropriate National Administrations and special consideration will be given to the safety requirements for classification purposes, as appropriate.

1.1.4 *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems*states general requirements for fire and gas detection systems. This Section also includes the additional fire detection requirements applicable for unattended machinery spaces and machinery spaces under continuous supervision from a centralised control station, *see Pt 6, Ch 1, 4.5 Fire detection alarm system*and *Pt 6, Ch 1, 5 Machinery operated from a centralised control station – CCS notation*, and incorporates requirements for accommodation units with spaces to house offshore personnel who are not members of the crew of the unit, *see Pt 3, Ch 4 Accommodation and Support Units*.

1.1.5 *Pt 7, Ch 1, 3 Systems for broadcasting safety information* states requirements for personnel warning systems, general alarms and public address systems.

1.1.6 *Pt 7, Ch 1, 4 Emergency lighting* states requirements for emergency lighting equipment.

1.1.7 *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas* states the alarms and safeguards required for heating ventilation and air conditioning systems to protect against ingress of gas into safe areas, as defined in *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

1.1.8 *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas* states requirements which apply where ventilation systems are installed in enclosed and semi-enclosed hazardous areas, as defined in *Pt 7, Ch 2, 6.2 Ventilation of hazardous spaces*.

1.1.9 *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* states requirements which apply to reduce fire and gas hazards in an emergency, by shutting down process plant and machinery.

1.1.10 *Pt 7, Ch 1, 8 Emergency release systems (ERS)* states requirements which apply to cargo transfer systems in an emergency, related to the release of the offloading configuration.

1.1.11 *Pt 7, Ch 1, 9 Riser systems* states requirements for control and alarms of riser systems for the assignment of the special features class notation **PRS**.

1.1.12 *Pt 7, Ch 1, 10 Protection against flooding* states requirements for the alarm and control of watertight closing appliances as required by *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines* and the requirements for the warning of ingress of water.

1.2 Documentation

1.2.1 The following documentation, as far as applicable to the unit, are to be submitted:

(a) For fire and gas systems:

- Fire and gas system design philosophy document.
- Fire and gas system design specification.
- Loss control or hazard analysis charts.
- Block diagram showing interface and power supply arrangements.
- Fire and gas system ‘cause and effect’ diagrams, including actions on heating, ventilating and air conditioning systems.
- Layout drawing showing the positions of fire and gas detector heads, manually operated call points, control panels and repeaters, cable routes, and fire zones.
- Details of the make and type numbers of all detector heads, manual call points and associated panels.
- Fire pump control, alarm, starting and inhibiting arrangements.
- For programmable electronic systems and networked systems, *see Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.5*.

(b) For public address and general alarms, unit status indicators and emergency lighting:

- Communications philosophy document.
- Block diagrams showing interfaces and power supply arrangements.
- Single line diagrams.
- Unit layout drawings showing location of fire zones, cryogenic spill areas, equipment and cable routes.
- For programmable electronic systems and networked systems, *see also Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.5*.

(c) For protection against gas and smoke in safe and hazardous areas:

- Layout drawing of drilling and/or process equipment and gas detectors.
- Ventilation system flow diagrams and gas detectors.

(d) For emergency lighting:

- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

(e) For emergency shut-down (ESD) systems:

- ESD philosophy document.
- Safety analysis tables based on results of HAZOP studies/reports.
- Process Flow Diagrams (PFDs).
- ESD safety analysis function evaluation charts (cause and effect matrices).

- Performance standards and criteria of the safety critical system.
- Process and Instrument Diagrams (P&IDs).
- Utility Flow Diagrams (UFDs)
- Cause and Effect diagrams (C&Es).
- Safety integrity level categorisation study for the instrument protective system.
- Instrument protective system reliability and availability calculations report.
- Alarm and trip schedules.
- Block diagrams showing interfaces and power supply arrangements.
- Physical arrangement of control panel.
- Details of manual trips, resets and override facilities.
- Layout drawings showing positions of the ESD system control panel, subpanels and manual trips.
- Wellhead and riser valve hydraulic schematics and control panels.
- ESD valve pneumatic and/or hydraulic schematics.
- For programmable electronic systems and networked systems, *see also Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.5*, *Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements*, *Pt 6, Ch 1, 2.11 Additional requirements for wireless data communication links* and *Pt 6, Ch 1, 2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems*.

(f) For emergency release systems (ERS):

- Safety integrity level categorisation study for the instrument protective system.
- Alarm and trip schedules.
- Block diagram showing interfaces and power supply arrangements.
- Physical arrangements of control panel.
- ERS valve pneumatic and/or hydraulic schematics.

(g) For watertight doors and other electrically operated closing appliances:

- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

1.3 Safety and communications equipment

1.3.1 Requirements for construction, detailed design, survey, inspection and testing of electrical and electronic equipment are contained in *Pt 6, Ch 1 Control Engineering Systems* and *Pt 6, Ch 2 Electrical Engineering* respectively.

1.3.2 Requirements for construction, detailed design, survey, inspection and testing of pneumatic and hydraulic equipment are contained in *Pt 5, Ch 1 General Requirements for Offshore Units*, *Pt 5, Ch 12 Piping Design Requirements*and *Pt 5, Ch 14 Machinery Piping Systems*.

1.3.3 Equipment used in safety and communication systems should be suitable for its intended purpose, and accordingly, whenever practicable, should be selected from the *List of Type Approved Products* published by Lloyd's Register (LR). A copy of the *Procedure for LR Type Approval System* will be supplied on application. For fire detection alarm systems, *see Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors 2.2.9*. For networked and programmable electronic systems, *see Pt 6, Ch 1, 1.2 Documentation required for design review 1.2.5*, *Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements*.

1.3.4 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see Pt 6, Ch 1, 1.3 Control, alarm and safety equipment*.

1.3.5 Assessment of performance parameters, such as accuracy, repeatability, etc. are to be in accordance with an acceptable National or International Standard.

Section 2
Fire and gas alarm indication and control systems

2.1 General requirements

2.1.1 This Section states general requirements for fire and gas detection alarm indication and control systems. *See also Pt 7, Ch 1, 5 Protection against gas ingress into safe areas*, *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas* and *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* for requirements concerning protection against gas leakage and shut-downs for process systems and associated equipment.

NOTE

The requirements for the audible and visual presentation of alerts and indicators should be determined by reference to the IMO Code on Alerts and Indicators 2009.

2.2 Fire and gas detection alarm panels and sensors

2.2.1 The requirements for fire detection alarms panels and sensors are given in *Pt 6, Ch 1, 2.8 Fire detection alarm systems* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). These Rules are also to be complied with where applicable for gas detection alarms panels and sensors and fire detection alarms panels and sensors specific to the unit's requirements. For units containing drilling facilities, specific reference should be made to the requirements of the *Chapter 9 - Fire Safety*, regarding fire and gas detection. For units with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities, *see Pt 11, Ch 13, 1.6 Gas detection*.

2.2.2 Automatic fire and gas detection alarm panels and sensors that satisfy the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors 2.2.3* to *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors 2.2.14* are to be fitted. Additional requirements for accommodation spaces and machinery spaces are given in *Pt 7, Ch 1, 2.5 Additional requirements for accommodation fire detection systems* and *Pt 7, Ch 1, 2.6 Machinery space fire detection systems*.

2.2.3 A fire and gas detection indicating panel is to be located at the centralised control station. A repeater panel is to be provided at a location which is readily accessible to responsible members of the crew at all times, at the fire control station, if fitted, and at, or adjacent to, the workstation for navigation and manoeuvring or the workstation for safety, on the navigating bridge, if fitted. The main panel and the fire-control station repeater are to indicate the source of the fire in accordance with arranged fire zones by means of a visual signal. Any other repeater panel(s) should indicate the general area of the fire zones affected.

2.2.4 The activation of any detector or manually operated call point shall initiate a visual and audible fire and gas detection alarm signal at the alarm and repeater panels. If the signal(s) has not been acknowledged within 2 minutes, an audible fire and gas alarm, having a characteristic tone, distinguishable from any other alarm, is to be automatically and immediately audible in all parts of the navigating bridge, if fitted, the workstations for navigation and manoeuvring, the fire control station, if fitted, all accommodation areas (with the exception, on accommodation units, of those for offshore personnel), and machinery spaces. The alarm need not be an integral part of the detection system.

2.2.5 In addition to the areas required by the Rules for Ships, facilities are to be provided in the fire and gas detection system to initiate manually the alarm referred to in *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors 2.2.4* from the following locations:

- Accommodation areas.
- The Unit Manager's office.
- Control stations in machinery and process areas.
- The main control station or fire-control station, if fitted.
- Throughout the installation in accordance with the defined fire and gas detection philosophy.

2.2.6 Fire and gas detection and alarm systems are to be provided with an emergency source of electrical power as required by *Pt 6, Ch 2, 3 Emergency source of electrical power*, and are also to be connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the main fire detection indicator panel, *see also Pt 6, Ch 2, 1.13 Bonding for the control of static electricity*. Reference should also be made to the guidance given in ISO 13702 to the supply capacity of UPS systems to defined emergency/critical facilities for the installation or unit. Failure of any power supply is to initiate an audible and visual alarm.

2.2.7 Fire and gas detectors are to be grouped as appropriate into zones conforming to passive fire protection boundaries and/or safe/hazardous area boundaries, as defined in *Pt 7, Ch 2 Hazardous Areas and Ventilation*. Further zones subdividing the above boundaries may also be arranged, where beneficial. Factors influencing zone boundaries include ventilation arrangements, bulkheads and the needs of the operating staff in locating and dealing with fire and gas incidents.

2.2.8 A zone/section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space or process area.

2.2.9 Fire and gas detection systems control and indicator panels, repeater panels, detectors heads, manual call points and short-circuit isolation units are to be suitable for their intended purpose. Detectors shall be certified by a recognised certifying authority for their intended purpose, where practicable, these should be selected from LR's *List of Type Approved Products*. Other bespoke design such as control panels, etc. (*see also Pt 7, Ch 1, 2.6 Machinery space fire detection systems 2.6.3*) should either be certified by a recognised certifying authority for its intended purpose (where practicable, these should be selected from LR's *List of Type Approved Products*) or the design appraised by Lloyd's Register.

2.2.10 The fire detection system, and any associated gas detection for the accommodation spaces, as required by *Pt 7, Ch 1, 2.5 Additional requirements for accommodation fire detection systems*, is to be integrated with, or suitably interfaced with, the main fire and gas detection control and indication panel. Similarly, any other permanent local fire and gas detection system is to be integrated with, or suitably interfaced with, the main fire and gas detection control and indication panel. Integrated systems should not result in reducing the integrity of the individual functions.

2.2.11 When it is intended that a particular loop or detector is to be temporarily switched off, reactivation need not be automatic after a preset time provided alternative acceptable means are in place to ensure re-activation has been successfully carried out.

2.2.12 Fire detector heads for the process and wellhead area, fusible plugs and linear electric elements for direct actuating of the deluge system may be used to supplement the automatic fire detection system.

2.2.13 Gas detectors are to be selected having regard to the flammable and/or toxic gases potentially present in each particular area or compartment and are to be sited having regard to the probable dispersal of the gas as governed by density, HVAC air flows and possible points of leakage, *see also Pt 7, Ch 1, 5 Protection against gas ingress into safe areas*and *Pt 7, Ch 1, 6 Protection against gas escape in enclosed and semi-enclosed hazardous areas*.

2.2.14 Means are to be provided so that the sensitivity of gas detectors can be readily tested in their mounted positions by the injection of span gas or other equivalent method.

2.2.15 In addition to the fixed gas detection system, portable gas detectors of each of the following types, together with any necessary test facilities for checking their accuracy, are to be provided for all anticipated gas hazards including the following:

- Hydrocarbon gas detectors range 0 to 100 per cent of the lower explosive limit.
- Toxic gas detectors.
- Oxygen concentration meters.

2.2.16 A suitable fixed hydrocarbon gas detection system for adjacent ballast tanks and void spaces of double-hull and double bottom spaces adjacent to hull hydrocarbon storage tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to these hull hydrocarbon storage tank spaces shall be fitted. The design of this fixed gas detection system shall be in accordance with the requirements of *Chapter 16 - Fixed Hydrocarbon Gas Detection Systems* of the *FSS Code - Fire Safety Systems – Resolution MSC.98(73)*.

2.3 Fire-extinguishing systems

2.3.1 The fire and gas detection system is to be arranged to initiate manually and automatically appropriate extinguishing system control actions, with the exception of asphyxiation gases such as carbon dioxide, *see Pt 7, Ch 1, 2.3 Fire-extinguishing systems 2.3.3*, by:

- actuating fire-fighting media and pre-release warnings;
- initiating fire and gas damper closures and stopping of ventilation fans to reduce the effect of fire and minimise ingress of gas;
- starting fire pumps.

The arrangements are to comply with *Pt 7, Ch 1, 2.3 Fire-extinguishing systems 2.3.2* to *Pt 7, Ch 1, 2.3 Fire-extinguishing systems 2.3.10*.

2.3.2 The operational state of fire-extinguishing facilities, including smothering gas, deluge, foam equipment, and fire water systems, are to be displayed on the main control panel and the fire control point repeater panel, if fitted, as follows:

- Charges of gas available for use, indication of zones into which gas has been released, and reserve capacity in hand.
- Indication of zones in which water deluge has been initiated.
- Liquid level in main installation (i.e. deck foam system, etc.) foam concentrate tank(s) and status of foam concentrate pumps and valves.
- Availability of fire pumps, indication of running and standby sets and positions of associated valves.
- Operational state of sprinkler systems.

2.3.3 The provision of manual and automatic release facilities for extinguishing media are to be designed to afford optimum protection to the installation, while giving proper regard to the safety of personnel as follows:

(a) Generally, the release of asphyxiating gases such as carbon dioxide should only be initiated locally by manual means since it is necessary to ensure that the space to be dealt with has been evacuated.
(b) Deluge systems and extinguishing gases which can be released without introducing an unacceptable health risk should be capable of being manually released locally and remotely at the fire and gas indication and control panel and at the fire-control station, if fitted.
(c) Automatic release of a fire-fighting system (i.e. deluge system, etc.) can be initiated by voting fire detectors or individual fire detectors.

2.3.4 Fire pumps are to be provided with automatic and manual starting facilities on the fire and gas detection indication and control panel. Automatic starting is to be initiated by activation of fire detection heads, operation of any manual call points or reduction of pressure in the fire main. Controls which start the standby set in the event of starting or running failure of the duty set are to be provided. Safeguards required in the event of flammable gas being detected in the vicinity of the fire pump are detailed under *Pt 7, Ch 1, 5.1 General requirements 5.1.9*. Manual starting facilities are to be provided adjacent to all fire pumps.

2.3.5 The design of extinguishing systems is to be in accordance with *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, and*FSS Code - Fire Safety Systems – Resolution MSC.98(73)*. However, installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of *Pt 11, Ch 11 Fire Prevention and Extinction* . For units containing drilling facilities, reference should be made to the requirements of the *Chapter 9 - Fire Safety*.

(a) When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units, *see also Pt 6, Ch 2, 3 Emergency source of electrical power*. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.
(b) The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire-resistant type, where they pass through other high fire risk areas.
(c) Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power. Exclusive circuits are to be used for the two units, *see also Pt 6, Ch 2, 3.1 General*. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.
(d) Each electrically driven carbon dioxide refrigeration unit is to be arranged for automatic operation in the event of loss of the alternative unit.

2.3.6 Fire and gas dampers and ventilation fans serving areas in which fire has been detected and confirmed by group voting are to be shut down automatically. Similar action is to be carried out prior to the release of extinguishing media. Manual shut-down from the main control panel and the fire control position is also to be available. The provision to close fire dampers manually from both sides of the bulkhead or deck, the integrity of which they are intended to maintain in line with the requirements of SOLAS and the MODU Code, should also be considered. To comply with those requirements, provision of means to close fire and gas dampers from a local position (such as, for instance, the space they serve) and a remote position (such as, for instance, the space where the fan is located) would be acceptable. Additionally:

(a) The electrical power required for the control and indication circuits of fire and gas dampers is to be supplied from the emergency source of electrical power. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.
(b) The control and indication systems for the fire and gas dampers are to be designed on the fail safe principle, with the release system having a manual reset.

2.3.7 The electrical power required for the control, indication and alarm circuits of fire doors is to be supplied from the emergency source of electrical power. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*. The

control and indication systems for the fire doors are to be designed on the fail safe principle, with the release system having a manual reset.

2.3.8 Automatic sprinkler systems are to be considered as part of the fire detection system.

2.3.9 Whenever any sprinkler comes into operation, an alarm and visual indication is to be initiated on the panels and repeaters required by *Pt 7, Ch 1, 2.3 Fire-extinguishing systems 2.3.2*.

2.3.10 The main fire and gas panel and the fire control point repeater, if fitted, are to indicate the location and zone/section of the sprinklers that have been initiated and the status of the system, as follows:

(a) Low level and pressure in the standing fresh water pressure tank.
(b) Start-up of the electrically driven pump which is brought into action automatically by the pressure drop in the system, before the standing fresh water charge in the pressure tank is completely exhausted.
(c) The status of the electrically driven or diesel-driven seawater fire pumps, that are required to start up when the fresh water system is exhausted.

2.3.11 The design of sprinkler systems is to be in accordance with *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, and *Chapter 8 - Automatic Sprinkler, Fire Detection and Fire Alarm Systems*. The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic changeover facilities located in, or adjacent to, the main alarm and detection panel.

2.4 Fire safety stops

2.4.1 Means of stopping all ventilating fans, with manual reset, are to be provided, outside the spaces being served, at positions which will not readily be cut off in the event of a fire. The provisions for machinery spaces are to be independent of those for other spaces.

2.4.2 Machines driving forced and induced draught fans, and independently driven pumps for lubricating, hydraulic or stored oil are to be fitted with remote controls, with manual reset, situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

2.4.3 Means of cutting off power to the galley, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

2.4.4 Fire safety stop systems are to be designed on the fail safe principle or, alternatively, the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see Pt 6, Ch 2, 5.3 Isolation and switching 5.3.10* of the Rules for Ships.

2.5 Additional requirements for accommodation fire detection systems

2.5.1 The requirements for accommodation fire detection systems are given in *Pt 6, Ch 2, 17.1 Fire detection and alarm systems* of the Rules for Ships, which are to be complied with where applicable.

2.5.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable as in *Pt 7, Ch 1, 2.5 Additional requirements for accommodation fire detection systems 2.5.3* to *Pt 7, Ch 1, 2.5 Additional requirements for accommodation fire detection systems 2.5.7*.

2.5.3 Fire detection systems for crew accommodation spaces and accommodation spaces for offshore personnel as defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations*of these Rules, and for accommodation and support units, are to comply with the additional requirements given below.

2.5.4 Where the fire detection system does not include means of remotely identifying each detector individually, a minimum of two zones/sections of detectors is to serve cabin spaces and they are to be arranged one on each side of the unit. Exceptionally, one zone/section of detectors may be permitted to serve both sides of the unit and more than one deck where it is satisfactorily shown that the protection of the unit against fire will not be reduced thereby.

2.5.5 Heat detectors used for the protection of accommodation spaces are to operate before the temperature exceeds 78°C, but not until the temperature exceeds 54°C.

2.5.6 The permissible temperature of operation of heat detectors may be increased by 30°C above the maximum deckhead temperature in drying rooms and other accommodation spaces having a normal high ambient temperature.

2.5.7 The maximum spacing of detectors in the living quarters is to be in accordance with *Table 1.2.1 Maximum fire detector spacing*. Other spacing complying with appropriate National Standards will be permitted.

Table 1.2.1 Maximum fire detector spacing

Type of detector	Maximum floor area perdetector, in m^2	Maximum distanceapart between centres,in metres	Maximum distanceaway from bulkheads,in metres
Heat	37	9	4,5
Smoke	74	11	5,5

2.6 Machinery space fire detection systems

2.6.1 An automatic fixed fire detection system is to be fitted in all machinery space (i.e. Category A and other machinery spaces). The automatic fire detection system is to meet the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors*and the additional requirements of *Pt 7, Ch 1, 2.6 Machinery space fire detection systems 2.6.2* to *Pt 7, Ch 1, 2.6 Machinery space fire detection systems 2.6.7* are to be satisfied. These requirements are also to be applicable for units to be assigned the **UMS** and **CCS** notations, *see Pt 6, Ch 1 Control Engineering Systems*.

2.6.2 An audible fire alarm is to be provided having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire alarm is to be immediately audible at the main control station and at all repeater stations. If the alarm is not accepted within two minutes, a general alarm is to be initiated throughout the unit.

2.6.3 Fire detection control units, indicating panels, detectors, manual call points and short-circuit isolation units are to be Type Approved. Whenever practicable they should be selected from the List of Type Approved Products published by Lloyd's Register (LR). For addressable systems, which also require to be Type Approved, *see Pt 6, Ch 1, 2.9 Programmable electronic systems – General requirements*.

2.6.4 When it is intended that a particular loop is to be temporarily switched off locally, this state is to be clearly indicated at the main fire detection control panel.

2.6.5 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective.

2.6.6 Except in spaces of restricted height and where their use is particularly appropriate, detection systems using only heat (thermal) detectors shall not be permitted.

2.6.7 For machinery spaces utilising smoke detection or a combination of smoke and heat detection, the spacing of detectors should meet the guidance given in *Table 1.2.1 Maximum fire detector spacing* for maximum fire detector spacing. However greater spacing of smoke and heat fire detection than that detailed in *Table 1.2.1 Maximum fire detector spacing* may be implemented in areas also provided with flame detector coverage.

2.7 Fire detection systems for other general enclosed spaces (enclosed services spaces / control stations / corridors and stairways)

2.7.1 An automatic fixed fire detection system is to be fitted in enclosed general spaces where a credible fire risk has been identified. The automatic fire detection system is to meet the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors*, and also *Pt 7, Ch 1, 2.5 Additional requirements for accommodation fire detection systems* or *Pt 7, Ch 1, 2.6 Machinery space fire detection systems* where appropriate to the protected general space. Spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. need not be fitted with an automatic fixed fire detection system.

2.8 Fire detection systems for topsides utility modules (i.e. power generation, boilers, water injection etc.)

2.8.1 An automatic fixed fire detection system is to be fitted in topsides utility modules where a credible fire risk has been identified. The automatic fire detection system is to meet the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors* and the additional requirements of *Pt 7, Ch 1, 2.8 Fire detection systems for topsides utility modules (i.e. power generation, boilers, water injection etc.) 2.8.2* to *Pt 7, Ch 1, 2.8 Fire detection systems for topsides utility modules (i.e. power generation, boilers, water injection etc.) 2.8.7* are to be satisfied.

2.8.2 An audible fire alarm is to be provided having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire alarm is to be immediately audible at the main control station and at all repeater stations along with initiating the general alarm throughout the unit.

2.8.3 Fire detection control units, indicating panels, detectors, manual call points and short-circuit isolation units are to be Type Approved. Whenever practicable they should be selected from the List of Type Approved Products published by Lloyd's Register (LR).

2.8.4 When it is intended that a particular detector is to be temporarily switched off locally, this state is to be clearly indicated at the main fire detection control panel.

2.8.5 If the utility module is of an open or partially open construction, flame detection is to be provided. The number and position of utilised flame detectors is to ensure an appropriate coverage of the fire risk associated with the utility module.

2.8.6 Except in enclosed utility modules of restricted height and where their use is particularly appropriate, detection systems using only heat (thermal) detectors shall not be permitted.

2.8.7 For enclosed utility modules utilising smoke detection or a combination of smoke and heat detection, the spacing of detectors should meet the guidance given in *Table 1.2.1 Maximum fire detector spacing* for maximum fire detector spacing. However greater spacing of smoke and heat fire detection than that detailed in *Table 1.2.1 Maximum fire detector spacing* may be implemented in areas also provided with flame detector coverage.

2.9 Fire and gas detection systems for topsides hydrocarbon process modules

2.9.1 An automatic fixed fire and gas detection system is to be fitted in topsides hydrocarbon process modules. The automatic fire and gas detection system is to meet the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors* and the additional requirements of *Pt 7, Ch 1, 2.9 Fire and gas detection systems for topsides hydrocarbon process modules 2.9.2* to *Pt 7, Ch 1, 2.9 Fire and gas detection systems for topsides hydrocarbon process modules 2.9.8* are to be satisfied.

2.9.2 An audible fire and gas alarm is to be provided having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire and / or gas alarm is to be immediately audible at the main control station and at all repeater stations along with initiating the general alarm throughout the unit.

2.9.3 Fire and gas detection control units, indicating panels, detectors, manual call points and short-circuit isolation units are to be Type Approved. Whenever practicable they should be selected from the List of Type Approved Products published by Lloyd's Register (LR).

2.9.4 When it is intended that a particular detector is to be temporarily switched off locally, this state is to be clearly indicated at the main fire and gas detection control panel.

2.9.5 If the process module is of an open or partially open construction, flame detection is to be provided. The number and position of utilised flame detectors is to ensure an appropriate coverage of the fire risk areas associated with the process module.

2.9.6 Except in enclosed process modules of restricted height and where their use is particularly appropriate, fire detection systems using only heat (thermal) detectors shall not be permitted.

2.9.7 For enclosed process modules utilising smoke detection or a combination of smoke and heat fire detection, the spacing of fire detectors should meet the guidance given in *Table 1.2.1 Maximum fire detector spacing* for maximum fire detector spacing. However greater spacing of smoke and heat fire detection than that detailed in *Table 1.2.1 Maximum fire detector spacing* may be implemented in areas also provided with flame detector coverage.

2.9.8 The number and position of utilised gas detectors is to ensure an appropriate coverage of the hydrocarbon leak risks associated with the process module.

2.10 Fire and gas detection systems for drilling areas on mobile offshore drilling units

2.10.1 An automatic fixed fire detection system is to be fitted in drilling areas with a fire risk. This is to be supplemented with an automatic fixed gas detection system fitted in drilling areas with a gas release risk. The automatic fire and gas detection system is to meet the requirements of *Pt 7, Ch 1, 2.2 Fire and gas detection alarm panels and sensors* and the additional requirements of *Pt 7, Ch 1, 2.10 Fire and gas detection systems for drilling areas on mobile offshore drilling units 2.10.2* to *Pt 7, Ch 1, 2.10 Fire and gas detection systems for drilling areas on mobile offshore drilling units 2.10.9*are to be satisfied.

2.10.2 An audible fire and gas alarm is to be provided having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire and / or gas alarm is to be immediately audible at the main control station and at all repeater stations along with initiating the general alarm throughout the unit.

2.10.3 Fire and gas detection control units, indicating panels, detectors, manual call points and short-circuit isolation units are to be Type Approved. Whenever practicable they should be selected from the List of Type Approved Products published by Lloyd's Register (LR).

2.10.4 When it is intended that a particular detector is to be temporarily switched off locally, this state is to be clearly indicated at the main fire and gas detection control panel.

2.10.5 If the drilling area is of an open or partially open construction, flame detection is to be provided. The number and position of utilised flame detectors is to ensure an appropriate coverage of the fire risk areas associated with the drilling area.

2.10.6 Except in enclosed drilling modules of restricted height and where their use is particularly appropriate, fire detection systems using only heat (thermal) detectors shall not be permitted.

2.10.7 For enclosed drilling areas utilising smoke detection or a combination of smoke and heat fire detection, the spacing of fire detectors should meet the guidance given in *Table 1.2.1 Maximum fire detector spacing* for maximum fire detector spacing. However greater spacing of smoke and heat fire detection than that detailed in *Table 1.2.1 Maximum fire detector spacing* may be implemented in areas also provided with flame detector coverage.

2.10.8 The number and position of utilised gas detectors is to ensure an appropriate coverage of the hydrocarbon leak risks associated with the process module.

2.10.9 For mobile offshore drilling units reference also needs to be made to the various requirements within the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26) 9.11 Flammable gas detection and alarm system* and *9.12 Hydrogen sulphide detection and alarm system*.

■ *Section 3*
Systems for broadcasting safety information

3.1 General

3.1.1 This Section states requirements for safety systems which broadcast warning of existing and potential hazards present on the unit and advise personnel on board of necessary actions they need to take.

NOTE

The requirements for the sound pressure levels to be provided by the public address system and audible alarms should be determined by reference to the *LSA Code - International Life-Saving Appliance Code – Resolution MSC.48(66)* and the *Code on Alerts and Indicators, 2009*.

3.2 Public address system

3.2.1 The requirements for public address systems are given in *Pt 6, Ch 2, 18.3 Public address system* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable. In machinery spaces and other locations with high ambient noise levels, whether continuous or intermittent, audible alarms should be supplemented by visual alarms.

3.2.3 A public address (PA) system is to be provided which is to be audible in all parts of the unit. The PA microphones are to be located at the main control station and at the fire-control station and/or navigating bridge, if fitted. Additional microphones may be provided at other suitable locations, e.g. in the Unit Manager’s office.

3.2.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

3.2.5 For mobile offshore drilling units reference also needs to be made to the various requirements within the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26) 5.7 Alarms and internal communication* for public address systems.

3.3 General emergency alarm systems

3.3.1 The requirements for general emergency alarm systems are given in *Pt 6, Ch 2, 18.2 General emergency alarm system* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.3.2 A general alarm (GA) system is to be provided which is to be audible in all parts of the unit. Alarm signal devices are to produce a distinctive and strong note.

3.3.3 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

3.3.4 The alarm signal used should be limited to: general emergency, toxic gas (hydrogen sulphide etc. if a credible risk exists), combustible gas, fire and abandon unit.

3.3.5 For mobile offshore drilling units reference also needs to be made to the various requirements within the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)5.7 Alarms and internal communication* for general alarm systems.

3.3.6 For mobile offshore drilling units, in addition to the various requirements of the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)5.7 Alarms and internal communication* for general alarm systems, it should be ensured that at least the following spaces are capable of initiating a general emergency alarm:

(a) Main control station;
(b) Drilling console;
(c) Navigation Bridge (if any); and
(d) Fire control station (if any).

3.4 Fire-extinguishing media release alarms

3.4.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by *Pt 6, Ch 2, 3.1 General*, and also connected to the main source of electrical power, with automatic changeover facilities located in or adjacent to the fire-extinguishing medium release panel. Failure of any power supply is to operate an audible and visual alarm, *see also Pt 6, Ch 2, 1.14 Alarms* and *Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

3.5 Escape route or low location lighting (LLL)

3.5.1 Escape route or low level location lighting (LLL), in the form of either electrically powered systems or photo-luminescent strip indicators, is to be provided in accordance with the requirements of *3.2 Means of escape in passenger ships .2.15*. Where electrically powered systems are used the arrangements are to comply with the requirements of this sub-Section.

3.5.2 Where an electrically powered system is used, the LLL system is to be provided with an emergency source of electrical power as required by *Pt 6, Ch 2, 3.1 General* and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power*. For Accommodation Units the LLL system is to be provided with an emergency source of electrical power as required by *Pt 3, Ch 4, 2 Structure* and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. The system is to be capable of being operated under fire conditions, *see also* IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 12.12.2.4 and*Pt 6, Ch 2, 1.16 Operation under fire conditions* of the Rules for Ships.

3.5.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire, in any one fire zone or deck, does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with Pt 6, Ch 2,10.5.3 of the Rules for Ships, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL, for a minimum period of 60 minutes. If the accommodation or part of the accommodation is classified as the Temporary Refuge, the LLL integral batteries are to have a minimum supply capacity of 60 minutes or a period in excess of 60 minutes if the Temporary Refuge is to be rated to maintain integrity for a period in excess of 60 minutes. Where these units are installed within cabins for crew or offshore personnel, or within associated corridors, the batteries are to be of the sealed type, *see Pt 6, Ch 2, 11.2 Testing*.

3.5.4 The performance and installation of lights and lighting assemblies are to comply with ISO 15370: *Ships and marine technology – Low location lighting on passenger ships – Arrangement*.

3.6 Mud system level alarms

3.6.1 For mobile offshore drilling units a suitable audible and visual alarm to indicate significant increase or decrease in the level of the contents of the mud pit is to be provided at the control station for drilling operations and at the mud pit. Equivalent means to indicate possible abnormal conditions in the drilling system may be considered by LR.

■ *Section 4*
Emergency lighting

4.1 General requirements

4.1.1 The requirements for emergency lighting are given in *Pt 6, Ch 2, 18.1 Emergency lighting* of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.1.2 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

■ *Section 5*
Protection against gas ingress into safe areas

5.1 General requirements

5.1.1 Heating ventilation and air conditioning systems serving safe areas are to be provided with alarms and safeguards required by *Pt 7, Ch 1, 5.1 General requirements 5.1.2* to *Pt 7, Ch 1, 5.1 General requirements 5.1.9*, to protect against hazards created by the ingress of gas.

5.1.2 Gas detectors are to be provided in or close to all air intakes serving safe areas. They are to be capable of initiating early warning of the presence of flammable and toxic gases likely to be present on the unit, as appropriate to its purpose or service. The detectors are also to be capable of initiating relevant shut-down actions, should the concentration of gas increase above the early warning level. To minimise nuisance shut-downs, consideration should be given to the provision of duplicated or triple redundant detector heads in each inlet operating in a voting configuration.

5.1.3 In addition to the detectors required by *Pt 7, Ch 1, 5.1 General requirements 5.1.2*, for exhaust outlets of accommodation modules adjacent to gas hazardous areas, consideration should be given to provide gas detectors to give warning of ingress of gas when the ventilation system is shut down.

5.1.4 Automatically closed dampers are to be provided in all intakes and exhausts. When the gas detectors required by *Pt 7, Ch 1, 5.1 General requirements 5.1.2* and, if fitted, those to which *Pt 7, Ch 1, 5.1 General requirements 5.1.3* refers, have detected gas demanding shut-down action, all HVAC inlet and exhaust fans and dampers associated with the space/point where ingress of gas has been detected are to be shut down and closed in addition to the damper of the duct in which gas has been detected. No reliance is to be placed on solely shutting dampers without also shutting down the associated fan motors. Dampers utilised to mitigate against the ingress of gas are to be suitably rated for this service.

5.1.5 Enclosed spaces with no source of release, but which contain sources of ignition such as machinery rooms, accommodations blocks or electrical equipment rooms are to be provided with fast-response gas detection at the air inlets, which are set with a suitably low gas detection level to initiate appropriate alarm and trip alarm functionality. The inlet gas detection should be located upstream of suitably rated fire and gas dampers. This is to ensure that an ignitable concentration of gas is prevented from entering an area containing an ignition source. The passage of an ignitable concentration of gas in the ducts should be stopped before it crosses the boundary of the protected space. Total response time of detectors, control systems and dampers should mitigate against an ignitable concentration of gas entering the ventilated space. As such, inlet ventilation dampers are to be designed to be fully closed within a minimum of five seconds of gas detection at the associated ventilation air inlet gas detector. Other mitigating measures that can be considered are:

- all machinery and electrical equipment, if any, fitted in the ducting being of a type suitable for Hazardous area location as applicable , *see Pt 7, Ch 2, 5 Machinery in hazardous areas* and *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*;
- early closure of dampers being initiated upon activation of gas detection system(s) in the process area, where applicable;
- hydrocarbon concentration within the ducting being the subject of a dispersion analysis, to allow assessment of hazards created, if any, to the machinery space being ventilated.

5.1.6 Where a machinery space is not served by redundant air intake ducts, consideration should be given to the provision of gas detection within the space. Consideration should also be given to the isolation of electrical equipment, other than that suitable for installation within a Zone 1 location, *see Pt 7, Ch 2, 8.1 General 8.1.4*, when flammable gas is detected within the space.

5.1.7 The alarms for loss of ventilation and loss of overpressure required by *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area* may be incorporated into the fire and gas central panel.

5.1.8 Consideration is to be given to the provision of gas detection within emergency generator spaces and their switchboard spaces as well as in the ventilation system intakes. In the event of gas being detected in the air intakes, the ventilation system intake and exhaust fan dampers are to be shut down and associated fan motors are to be stopped. The emergency generator may continue to run, provided that aspiration air is drawn separately from outside the space and the engine induction and exhaust arrangements comply with the relevant requirements of *Pt 7, Ch 2, 7 Engines in hazardous areas*. However, if gas is detected within the emergency generator enclosure, emergency switchroom, or at the engine air intake, the emergency generator is to be shut down.

5.1.9 Diesel-driven fire pumps will not require to be shut down if gas is detected in the area or space in which they are sited, provided that no electrical equipment, other than that suitable for installation in a Zone 1 location, *see Pt 7, Ch 2, 8.1 General 8.1.4*, is required to remain in operation. Should any equipment not be suitable for such installation (firewater pump drives, i.e. diesel drive units, etc. are often not certified and are therefore not rated to operate in a hazardous atmosphere), they are to be suitably protected by other means (i.e. housed in a safe area, within a suitably rated enclosure with fire rated and gastight barriers, designed to run with the firewater pump drive enclosure shut down (i.e. enclosure fire and gas dampers closed, etc.), diesel drives provided with engine overspeed protection, etc.) to mitigate against gas ingress and enable the drive to continue to operate. Additionally, such pumps should not be started up with gas present, and any electrical starting circuits and control and alarm circuits not suitable for operation in a Zone 1 location are also to be isolated automatically by the fire and gas panel.

5.1.10 Ventilation systems serving Hazardous areas are to be fully segregated from ventilation systems serving Non- Hazardous areas.

5.1.11 Drain systems serving Hazardous areas are to be fully segregated from drain systems serving Non-Hazardous areas.

■ *Section 6*
Protection against gas escape in enclosed and semi-enclosed hazardous areas

6.1 General

6.1.1 Enclosed and semi-enclosed hazardous areas as defined in *Pt 7, Ch 2, 1.2 Definitions and categories* are to be provided with alarms and safe guards required by *Pt 7, Ch 1, 6.1 General 6.1.2*to *Pt 7, Ch 1, 6.1 General 6.1.4* to give protection against accidental release of hydrocarbon and toxic gases.

6.1.2 Appropriate gas detectors are to be provided, to give warning of gas release in the following locations:

- Drill floor.
- Mudrooms.
- Shale shaker space.
- Wellhead and riser areas.
- Adjacent to process equipment.
- Machinery rooms with gas-fuelled equipment.
- Turret area.
- Any other location where there is a significant risk of a leakage of gas or of liquid liable to release flammable vapour.

6.1.3 Detectors are to be capable of initiating early warning of the presence of gas and are also to be capable of initiating relevant shut-down actions via the emergency shut-down system called for in *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* when higher gas concentrations are detected. To minimise nuisance shut-downs consideration should be given to trips initiated by confirmed response by more than one detector within the space concerned or the provision of similar voting arrangements.

6.1.4 Gas turbines and their enclosures are to be fitted with flammable gas detectors at the following locations:

- Turbine air intakes.
- Ventilation system air intakes.

- Ventilation system exhausts.

The presence of gas in the turbine air intake and/or ventilation system air intake is to initiate shut-down of the turbine and the ventilation system. If gas is sensed only in the ventilation exhaust, the ventilation system is to continue running and the turbine is to be shut down. Proposals involving shutting down and inerting the turbine machinery enclosure for the conditions described will be given special consideration.

6.1.5 If an enclosed hazardous area is supplied with a ventilation system, the presence of gas in the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. However, other suitable shutdown functionality (i.e. tripping of electrical equipment within the area, process plant shut-down and emergency depressurisation, etc.) are to be initiated dependent upon the degree of hazard.

■ *Section 7*
Emergency shutdown (ESD) systems

7.1 General

7.1.1 An emergency shutdown (ESD) system represents a layer of protection that mitigates and attempts to prevent a hazardous situation from occurring. An ESD system is to be provided when any process presents a hazard which could affect the safety of personnel, the overall safety of the unit or the pollution of the environment. Guidance on identifying hazards and assessing risk is provided in ISO 17776, *Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment*. The system is to satisfy the requirements of this sub-Section.

7.1.2 The ESD system is to operate in association with process plant and safety critical facilities to incorporate levels of hierarchical shutdown appropriate to the degree of hazard to personnel, the unit and the environment. The arrangements are to be derived using hazard analysis techniques. Where the unit is to be connected to another installation, such as shore, vessel, other unit, etc. linked ESD systems should be provided and be capable of transmitting ESD signals to any of the connected installations and vice versa, *see Pt 7, Ch 1, 7.4 Linked ESD systems*.

7.1.3 The operation of the ESD system is to be initiated manually. In addition, operation is also to be initiated automatically by signals derived from the fire and gas and cryogenic spill detection systems as well as signals derived from process and other equipment sensors. Drilling equipment is to be shut down automatically in a controlled manner upon activation of a high level or drilling ESD. ESD system is also to be activated upon loss of instrument air.

NOTE

Guidance on manual and automatic inputs is given in *Pt 11, Ch 18, 4.1 General 4.1.2* and Ch 18,.10.1.4 .

7.1.4 ESD initiation is to activate audible and visual alarms in the central control room (CCR) and at strategic locations outside the CCR. The activation of a manual ESD activation point is to initiate the general alarm of the unit.

7.1.5 An ESD system shall continuously provide adequate information at a central control station allowing personnel involved in managing an emergency to have necessary information. ESD system status shall be continuously monitored in the central control room (CCR). Items to be considered for monitoring are the following:

- ESD level initiation.
- ESD effects which have failed to be executed upon ESD activation.
- Failure of ESD system component.

7.1.6 ESD functions shall as far as practicable be functionally and physically independent from other systems/functions.

7.1.7 Manual ESD activation points for complete shutdown of the installations are to be provided at the central control room (CCR) and other suitable locations, e.g. at the helicopter deck and the emergency evacuation stations. Each manual ESD activation point on the installation is to be clearly identified. Manual ESD activation points are to be protected against inadvertent operation.

7.1.8 The ESD system is to be arranged with automatic changeover to a stand-by power supply, ensuring uninterrupted operation of the system, in the event of failure of the normal power supply.

7.1.9 Failure of any power supply to the ESD system is to operate an audible and visual alarm.

7.1.10 The stand-by power supply required by *Pt 7, Ch 1, 7.1 General 7.1.8* should be capable of supplying power for ESD functions for a minimum duration of 30 minutes.

7.1.11 Upon failure of protective system, logic solvers, sensors, actuators or power source, the operation of the plant and equipment is to revert automatically to the least hazardous condition.

NOTE

This requirement is normally realised by employing a fail safe design. Special consideration is given to subsea christmas tree solenoid valves, which are not normally energised. Part of these special considerations for subsea tree valves is typically to provide high integrity solenoid valves which de-energise via the ESD system and vent the hydraulic fluid from the subsea christmas tree actuators to the topsides hydraulic skid. This process will eventually close the subsea tree valve via loss of hydraulic pressure.

7.1.12 Hydrocarbon related components are to be equipped with primary and secondary protection as defined in ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Section B.2 or alternative relevant International or National Standard, to prevent or minimise the effects of an equipment failure within the process. Where provision of two means of protection cannot be achieved, special consideration must be given to the design of the alternative means.

7.1.13 High level ESD (as defined in accordance with *Pt 7, Ch 1, 7.1 General 7.1.2*, e.g. platform shut-down, production shut-down) should only be provided with a capability to reset each final element locally. Elements affected by low level ESD (as defined in accordance with *Pt 7, Ch 1, 7.1 General 7.1.2*, e.g. equipment or component shutdown) may be reset by means of a remote manual group reset operation from the central control room.

NOTE

High level ESD is typically related to total platform shut-down, platform evacuation, etc.

Low level ESD is typically classified as a process train trip, single package trip, etc.

7.1.14 Maintenance override facilities shall only be provided for ESD sensors where a secondary form of protection for stopping the process is available to the operator, and the operator has sufficient time to respond to the event. Maintenance overrides shall not be provided for manual ESD inputs (i.e. ESD pushbuttons). Consideration should be given to the number of inhibits applied at any one time to an ESD system, to ensure that the ESD function is not impaired. Physical key switches are to be used for applying overrides to high level, safety-critical shut-down system inputs. The amount of time that the key switch is enabled shall be timed and alarmed if the allowable time is exceeded.

7.1.15 Start-up overrides may be applicable to low level and similar trips during plant start-up. These overrides are to be cancelled automatically once the normal process condition has been reached or when a fixed period of time has expired.

7.1.16 Where arrangements are provided for overriding parts of an ESD system, they should be such that inadvertent operation is prevented. When an override is operated, visual indication is to be given at the central control room.

7.1.17 Upon activation of the ESD system there shall be no means of overriding/resetting the system until such time as the conditions that triggered the system are returned to a safe state.

7.1.18 Accumulators for pneumatic and hydraulic systems are to have sufficient capacity to allow the performance of one complete shutdown followed by reset and a further shutdown without the need for recharging the accumulator. Accumulator pre-alarms will also be fitted and signals should have suitable time delays.

7.1.19 Manual valves which are part of the safety control circuits shall be secured in the correct position to ensure no inadvertent operation.

7.1.20 All emergency shut-down and blow down valves shall be fitted with open and closed position limit switches and indicators. Valve position shall be indicated in the central control room (CCR) and locally.

7.1.21 Where ESD applications are to be implemented by programmable electronic systems, a risk-based approach, as described in IEC 61508-5, *Functional safety of electrical/electronic/programmable electronic safety related systems – Part 5: Examples of methods for the determination of safety integrity levels* or alternative relevant International or National Standard, for the specification and design of these systems is to be adopted. The ESD system is to comply with the requirements of IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems* or alternative relevant International or National Standard and, as far as applicable, those of IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*. Each measure to control or mitigate hazards is to be assigned an appropriate degree of risk reduction which contributes to the overall risk reduction. The risk reduction figure is to be translated into performance standards for each measure which will be specified in terms of functionality, availability, reliability, survivability and interactions (FARSI), *see also Pt 6, Ch 1, 2.13 Programmable electronic systems – Additional requirements for integrated systems*.

7.1.22 The implementation of a programmable electronic system to perform high safety integrity level functions or any other form of logic solver (i.e. relay/solid state magnetic core) is to be via a suitable certified Safety Integrity Level (SIL) system, acceptable to LR, which will give an appropriate SIL for all SIL classified functions associated with the ESD system. This certification is to include calculations for Probability of Failure on Demand ($\mathrm{PDF}_{\mathrm{AVG}}$), architectural constraints in terms of safe failure fraction (SFF) and hardware fault tolerance (HFT), random failures as specified in IEC 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems*, Section 7.4.2.2 or alternative relevant International or National Standard.

7.1.23 ESD control units are, where practicable, to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System* for an environmental category appropriate for the locations in which they are intended to operate.

7.1.24 Status, diagnostic and alarm information exchange executed by read-only soft links to remote digital systems for display purposes may be provided, as applicable, by the Integrated Control and Safety System (ICSS) or matrix panels, *see Pt 6, Ch 1, 2.13 Programmable electronic systems - Additional requirements for essential services and safety critical systems 2.13.9* of the Rules for Ships.

7.1.25 Access to the system is to be restricted so that software may only be modified by suitably authorised personnel.

7.1.26 Consideration is to be given to the segregation of cabling and wiring associated with ESD functions from that associated with power cables.

7.1.27 All ESD equipment that is critical to provide an effective shut-down shall be protected against mechanical/environmental damage until the intended shut-down sequence is completed.

7.2 Electrical equipment

7.2.1 In addition to the requirements of *Pt 7, Ch 1, 7.1 General*, any electrical equipment which has to remain operational in a Major Accident Event (e.g. rupture of a process vessel or pipe) and is therefore capable of being subjected to a flammable atmosphere is to be of a type suitable for installation in a Zone 1 location, *see Pt 7, Ch 2, 8.1 General 8.1.6*.

7.2.2 Electrical equipment which, on drilling units, is required to function following an emergency shut-down and provide continued operation during an ongoing emergency should be selected in accordance with the requirements of *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* and IEC 61892-7, *Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas*. Such equipment should be suitable for its intended application and be suitable for installation in Zone 1 locations; however, consideration will be given to alternative arrangements where they are shown to provide an equivalent level of safety to the satisfaction of LR.

NOTE

A Major Accident Event is defined in the Offshore Installations (Safety Case) Regulations 2005 (SI 2005/3117) as:

(a) A fire, explosion or release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;
(b) Any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation;
(c) The collision of a helicopter with the installation;
(d) The failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations; or
(e) Any other event arising from a work activity resulting in death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it.

7.3 Testing

7.3.1 Facilities are to be available for testing of both input/output devices and internal functions of the ESD system.

7.3.2 Factory Acceptance Test (FAT) is required for logic solvers implementing safety instrumented functions. A FAT is to be conducted in accordance with IEC 61511-1:2003, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*, Section 13 or alternative relevant International or National Standard.

7.3.3 Function tests are to be conducted in accordance with *Pt 6, Ch 1, 7.1 General* where applicable, ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Annex G, or alternative relevant International or National Standard.

7.4 Linked ESD systems

7.4.1 A linked ESD system communicates ESD signals from unit to shore/vessel and vice versa, via a compatible interface.

7.4.2 A linked emergency shut-down (ESD) shall initiate a controlled cargo transfer process shut-down.

7.4.3 All relevant initiation signals at either end of the link shall be processed and transmitted through an established ESD link, as a single ESD signal and not as individual signals.

7.4.4 An independent back-up system shall be provided so that a common failure mode is reduced as far as is reasonably practicable.

7.4.5 Due consideration should be afforded to the sequence and timing of closure of ESD valves on both units, in order to mitigate for the hydraulic surge in the transfer lines.

7.4.6 A high-level functional flowchart of the linked ESD and related systems should be provided in the central control room (CCR).

7.4.7 The use of electric links should be reviewed to ensure protection against ignition during accidental cable damage and connect/disconnect operations.

7.4.8 Where an electrical ESD link is used, a standardised pin configuration should be adopted, as per ISO 28460:2010, *Petroleum and natural gas industries – Installation and equipment for liquefied natural gas – Ship-to-shore interface and port operations*, Section 14.4 or alternative relevant International or National Standard. Consideration will be given to use of other pin configurations.

7.4.9 Should additional information, such as telephone links, data for mooring tension monitoring systems, etc. be transferred through the linked ESD system, provision is to be made to ensure that these additional features do not interfere with the primary function of the linked ESD system.

7.4.10 Where additional services are supplied from shore, such as onshore power supply, these must be considered as part of the ESD safety analysis function evaluation charts, *see Pt 7, Ch 1, 1.2 Documentation 1.2.1*.

7.4.11 Upon failure of ESD link between a non-manned installation and its remote control centre, there shall be an alternative facility to shut down the non-manned installation automatically.

■ *Section 8*
Emergency release systems (ERS)

8.1 General

8.1.1 Where the cargo transfer system between two units is fitted with a linked emergency shut-down (ESD) system, *see Pt 7, Ch 1, 7.4 Linked ESD systems*, and an emergency release system (ERS), ensuring the coordinated operation of both ESD and ERS functions and the prevention of overpressure in the transfer system, the requirements of this Section are to be complied with. The design of ERS systems is to comply with the requirements of EN1474-1 and 3, *Installation and equipment for liquefied natural gas – Design and testing of marine transfer systems* or alternative relevant International or National Standard and this sub-Section.

8.1.2 The function of the ERS protects the offloading configurations by disconnecting them, should the units drift out of their operating envelope.

NOTES

(a) Examples of offloading configurations are the following:

- Marine transfer arms systems.
- Rigid supported hose systems.
- Aerial flexible hoses.
- Floating flexible hoses.

(b) Operating envelope is the maximum spatial area in which the presentation flange of an offloading configuration system can operate safely.

8.1.3 Means are to be provided to activate the Emergency Release System (ERS) manually from the central control station and locally, where the cargo transfer process is monitored or visually observed. Should the marine transfer arm/hose extend

outside its operational envelope, this is to be detected by sensors, leading to automatic activation of the emergency release system (ERS).

8.1.4 Manual ERS activation points are to be protected against inadvertent operation.

8.1.5 In an emergency, when the offloading configuration requires to be disconnected, this should occur as a two-stage process:

- First stage: deployment of the linked ESD system, *see Pt 7, Ch 1, 7.4 Linked ESD systems*.
- Second stage: activation of the Emergency Release System (ERS), *see Pt 7, Ch 1, 8.1 General 8.1.6*.

The design of the systems should be such that the second stage cannot be activated unless the functions of the first stage have commenced.

8.1.6 The ERS activation sequence is as follows:

- simultaneous closure of the interlocking ERS isolating valves;
- activation of the Emergency Release Coupler (ERC);
- disconnection of the arms/hoses;
- retraction to safe position.

Each stage in the sequence must be complete before the next commences.

8.1.7 ERS activation procedures are to be clearly posted at the ERS operating location(s).

8.1.8 The emergency release system (ERS) is to be independent and separate from the linked ESD system. Although the ERS system is to be independent from the ESD system, it may share a common power source, provided that a failure in either system does not render the other system inoperable, e.g. failure in hydraulic or pneumatic control lines.

8.1.9 All relevant initiation signals at either end of the link shall be processed and transmitted through an established ERS link, as a single ERS signal and not as individual signals.

8.1.10 The overall design of the offloading configuration, ESD and ERS systems should consider offloading environmental conditions and locations. The design of this system shall take into account possible ice build-up.

8.1.11 The ERS operating system shall be designed to retain sufficient stored energy to release all transfer arms/hoses in the event of unit blackout and the non-availability of provided utilities. Loss of power should not result in automatic activation of the ERS.

8.1.12 An uninterruptible power supply is to be provided to supply power to the logic and control systems.

8.1.13 Electrical, electronic and programmable components which are part of the safety system shall comply with IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety related systems*.

8.1.14 Access to the system is to be restricted so that software may only be modified by suitably authorised personnel.

8.2 Electrical

8.2.1 In addition to the requirements of *Pt 7, Ch 1, 8.1 General*, any electrical equipment which has to remain operational in a Major Accident Event (e.g. rupture of a process vessel or pipe) and is therefore capable of being subjected to a flammable atmosphere is to be of a type suitable for installation in a Zone 1 location, *see Pt 7, Ch 2, 8.1 General 8.1.6*.

8.2.2 Electrical isolation between units must be maintained during cargo transfers and connection/disconnection operations.

8.2.3 Each offloading configuration should have an electrical isolation arrangement installed at one of its connection flanges, to isolate electrically ship from the transfer arm/hose. The electrical resistance of the isolating flange is to be between 1 kΩ and 100 MΩ.

8.3 Testing

8.3.1 Factory Acceptance Test (FAT) is required for logic solvers implementing safety instrumented functions. A FAT is to be conducted in accordance to IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*, Section 13 or alternative relevant International or National Standard. Factory Acceptance Tests are to satisfy the requirements of EN1474-1:2008, *Installation and equipment for liquefied natural gas – Design and testing of marine transfer systems Part 1: Design and testing of transfer arms*, Section 8.4 or alternative relevant International or National Standard.

8.3.2 Function tests are to be conducted in accordance with *Pt 6, Ch 1, 7.1 General* where applicable, ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Annex G, or alternative relevant International or National Standard.

■ *Section 9* **Riser systems**

9.1 General

9.1.1 The provisions laid down in *Pt 3, Ch 5 Fire-fighting Units* for the assignment of the special features class notation **PRS** are to be complied with.

9.1.2 The location where the riser(s) is situated, inboard of the installation or unit, is to be safeguarded by an appropriate fire and gas detection system complying with the requirements of *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems*. In the event that a fire or confirmed gas leakage is detected, effective automatic means of closing down the riser(s) are to be provided.

9.1.3 The riser system is to be equipped with an emergency shut-down valve, fitted as close to the waterline as possible, but above the splash zone. The valve is to be of the self-actuating type with its own localised control medium and interfaces with the installation ESD, as specified in *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*.

9.1.4 Testing facilities which actuate the inboard riser valves are to be provided, and initiated periodically to ensure actuator breakout forces are achieved.

9.1.5 The riser system is to be provided with means of leakage monitoring and to ensure integrity of the riser system (Trunk and Infield Pipelines, as applicable). The leak detection system should take the following parameters into consideration:

- Continuous mass balance (fiscal).
- Continuous volumetric balance corrected for temperature and pressure (fiscal).
- Continuous monitoring of rate of change of pressure.
- Continuous monitoring of rate of change of flow.
- Low pressure alarm or trip.
- High flow alarms.

The leak detection system on **Infield Lines** should take the following parameters into consideration where relevant:

- Subsea choke position.
- Multiphase subsea flowmeter.
- Infield metering (when installed).
- Continuous monitoring of rate of change of pressure.
- Continuous monitoring of rate of change of flow.
- Low pressure alarm or trip.
- High flow alarm.

9.1.6 Control of the riser system is to be effected from a clearly defined control centre, provided with sufficient instrumentation to indicate the conditions at each end of the riser system and to ensure effective control, shut-down and disconnection.

9.1.7 Where more than one control centre is provided, the arrangements are to be such that only one control centre can start up the riser system at a given time. Clear indication is to be provided to show which centre is in control.

9.1.8 Independent means of voice communication are to be provided between the single point mooring end of the riser system and the control centre(s).

9.1.9 Alarms displayed in a control centre are to be audible and visual. An alarm event recorder is to be provided.

9.1.10 The riser system is required to be safely disconnected when the design limits are exceeded. Self-closing devices positioned as close to the rapid disconnecting point as possible are to be fitted so as to ensure accidental spillage at the junction is minimised. A suitable alarm is to be provided, warning that the design limits are reached.

Section 10
Protection against flooding

10.1 General requirements

10.1.1 The requirements for watertight and weathertight integrity and the general requirements regarding the control and closure of watertight and weathertight doors and hatch covers in order to satisfy the intact and damaged stability criteria are given in *Pt 4, Ch 1 General*and *Pt 4, Ch 8 Welding and Structural Details*, to which reference should be made.

10.1.2 A system of alarm displays and controls is to be provided which will ensure satisfactory supervision and control of watertight doors and hatch covers, and also in the case of column-stabilised units to give warning of ingress of water.

10.1.3 For column-stabilised units, the alarm displays and controls are to be provided at a centralised panel at the ballast control station, *see Pt 4, Ch 7, 3 Installation layout and stability*, *Pt 5, Ch 13, 4.6 Column-stabilised units* and *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units*.

10.1.4 For ship and self-elevating units, the alarm displays and controls are to be provided at a centralised panel either at the ballast control station, the main control station, the workstation for navigation and manoeuvring or the workstation for safety, on the navigating bridge, as applicable, *see Pt 4, Ch 8, 3 Secondary member end connections*.

10.1.5 Doors and hatch covers needed to ensure watertight integrity of internal openings and which are used during operation of the unit while afloat are to be remotely controlled. Detailed alarm, indication, and control requirements are given in *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches* for electrically operated watertight doors and hatch covers, and in *Pt 7, Ch 1, 10.3 Hydraulically operated watertight doors and hatch covers* for hydraulically operated watertight doors and hatch covers.

10.1.6 Doors and hatch covers needed to ensure watertight integrity of internal openings which are normally kept closed when the unit is afloat are to be provided with alarm indicators in accordance with *Pt 7, Ch 1, 10.4 Indicators for doors, hatch covers and other closing appliances*.

10.1.7 Doors and hatch covers needed to ensure watertight and weathertight integrity of external openings are to comply with *Pt 7, Ch 1, 10.1 General requirements 10.1.4* and *Pt 7, Ch 1, 10.1 General requirements 10.1.5*, as appropriate, in accordance with the requirements of *Pt 4, Ch 8 Welding and Structural Details*.

10.1.8 When other types of closing appliances (e.g. on ventilators) are required to be remotely controlled or alarmed in accordance with the requirements of *Pt 4, Ch 8 Welding and Structural Details*, the general requirements of this Section are to be complied with, as applicable.

10.1.9 Bilge level sensors, and water level indication required for column-stabilised units are to be in accordance with *Pt 7, Ch 1, 10.5 Bilge level and flood water level alarm and indication*.

10.2 Electrically operated watertight doors and hatches

10.2.1 The requirements for electrically operated watertight doors and hatches are given in *Pt 6, Ch 2, 18.1 Emergency lighting*of the Rules for Ships, which are to be complied with where applicable.

10.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable as in *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.3* to *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.5*.

10.2.3 Where watertight doors and hatch covers are to be operated electrically, the term ‘door’ is to be understood to include hatch covers.

10.2.4 Where the Rules for Ships refer to ‘bulkhead deck’ this should be substituted for ‘final water plane after damage’.

10.2.5 The ‘master mode’ switch is to be Type Approved in accordance with *Test Specification* Number 1 given in LR’s *Type Approval Scheme*.

10.3 Hydraulically operated watertight doors and hatch covers

10.3.1 Where watertight doors and hatch covers are operated hydraulically, the arrangements are to be equivalent to *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.1* and *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.2* to *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.5* for electrically operated doors and hatch covers.

10.3.2 Electrical indication arrangements for hydraulically operated doors and hatch covers are to meet the requirements of *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.1* and *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.2* to *Pt 7, Ch 1, 10.2 Electrically operated watertight doors and hatches 10.2.5*.

10.3.3 Where four or more doors or hatch covers are powered from a single hydraulic power unit, duplicated hydraulic pump units are to be provided.

10.4 Indicators for doors, hatch covers and other closing appliances

10.4.1 Indicators required by *Pt 7, Ch 1, 10.1 General requirements 10.1.6* and *Pt 7, Ch 1, 10.1 General requirements 10.1.7* on doors, hatch covers and other closing appliances which are intended to ensure the watertight integrity of the unit’s structure, are to meet the requirements of *Pt 7, Ch 1, 10.4 Indicators for doors, hatch covers and other closing appliances 10.4.2* to *Pt 7, Ch 1, 10.4 Indicators for doors, hatch covers and other closing appliances 10.4.3*.

10.4.2 The indicator system is to be designed on the fail-safe principle, such that, in the event of a fault, the system cannot incorrectly indicate that a door, hatch cover, or other closing appliance is fully closed. A green light is to indicate when a door, hatch cover or closing appliance is closed and a red light is to indicate that it is not fully closed or secured.

10.4.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors and hatch covers.

10.5 Bilge level and flood water level alarm and indication

10.5.1 Column-stabilised units are to be provided with arrangements to warn of high bilge level and ingress of water due to flooding in accordance with *Pt 7, Ch 1, 10.5 Bilge level and flood water level alarm and indication 10.5.2* to *Pt 7, Ch 1, 10.5 Bilge level and flood water level alarm and indication 10.5.4*, *see also Pt 5, Ch 13, 4.6 Column-stabilised units*.

10.5.2 Bilge high level alarms and water high level alarms are to be provided on a centralised control panel, situated in the ballast control room required by *Pt 6, Ch 1, 2.8 Ballast control systems for column-stabilised units*.

10.5.3 Bilge high level or water high level alarm sensors are to be installed in all compartments, which are large enough to affect stability and which are required to remain watertight to comply with the intact and damaged stability criteria. Tanks fitted with remote tank level indicators with displays other than in the ballast control room, are exempt from this requirement. The requirements for chain lockers are to comply with *Pt 5, Ch 13, 4.6 Column-stabilised units 4.6.9*.

10.5.4 Pump-rooms, propulsion rooms and machinery spaces category type A in lower hulls and columns are to be provided with two level sensors in each compartment, one for detection of high bilge water level, and a second detector to warn of flooding.

■ *Section 1* Hazardous areas – General

1.1 Application

1.1.1 Units for oil and gas exploitation, units with production and process plant, drilling plant, and other units where explosive gas-air mixtures are likely to be present are to be classified into 'hazardous areas' and 'non-hazardous areas' in accordance with the requirements of this Chapter, or alternatively, with an acceptable Code or Standard giving equivalent safety.

1.1.2 These requirements do not apply to the release of explosive gas-air mixtures as a consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 For special requirements relating to drilling, workover and wirelining operations, *see Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations*.

1.1.4 For special requirements relating to units intended for the storage of oil in bulk, *see Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*. For special requirements relating to units intended for the storage of liquefied gases in bulk or other hazardous liquids, *see Pt 7, Ch 2, 10 Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk* and *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes* and *Pt 11, Ch 10 Electrical Installations*.

1.1.5 The hazardous areas applicable to well testing will be specially considered.

1.2 Definitions and categories

1.2.1 A hazardous area is an area on the unit where flammable gas-air mixtures are, or are likely to be, present in sufficient quantities and for sufficient periods of time such as to require special precautions to be taken in the selection, installation and use of machinery and electrical equipment.

1.2.2 Hazardous areas may be divided into Zones 0, 1 and 2, defined as follows:

Zone 0: An area in which an explosive gas-air mixture is continuously present or present for long periods.

Zone 1: An area in which an explosive gas-air mixture is likely to occur under normal operating conditions.

Zone 2: An area in which an explosive gas-air mixture is unlikely to occur, and if it occurs, it will only persist for a short period.

Non-hazardous areas are those which are not classified as hazardous according to the above definitions.

1.2.3 An enclosed space is considered to be any building, room or enclosure, e.g. cabinet, within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

1.2.4 A semi-enclosed space is considered to be a space which is adjoining an open area where the natural ventilation conditions within the space are restricted by structures such as decks, bulkheads or windbreaks in such a manner that they are significantly different from those appertaining to the open deck, and where dispersion of gas may be impeded.

1.2.5 When an enclosed or semi-enclosed space is provided with a mechanical ventilation system which ensures at least 12 air changes/hour and no pockets of stagnant air within the space, such a space may be regarded as an open space.

1.2.6 An open space is an area that is open-air without stagnant regions where vapours are rapidly dispersed by wind and natural convection. Typically, air velocities will rarely be less than 0,5 metres per second and will frequently be above 2 metres per second.

1.2.7 Under normal operating conditions, a hazardous zone or space may arise from the presence of any of the following:

(a) Spaces or tanks containing any of the following:

- (i) Flammable liquid having a flash point not exceeding 60°C closed-cup test;
- (ii) Flammable liquid having a flash point above 60°C closed-cup test, heated or raised by ambient conditions to a temperature within 15°C of its flash point;
- (iii) Flammable gas.

(b) Piping systems or equipment containing fluid defined by *Pt 7, Ch 2, 1.2 Definitions and categories 1.2.7* and having flanged joints, glands or other fittings through which leakage of fluid may occur.

(c) Piping systems or equipment containing flammable liquid not defined by *Pt 7, Ch 2, 1.2 Definitions and categories 1.2.7*, and having flanged joints, glands or other fittings through which leakage of fluid in the form of a fine spray or mist could occur.

(d) Equipment associated with processes such as battery charging or electrochlorination which generate flammable gas as a by-product, and having vents or other openings from which gas may be released.

1.2.8 Release of explosive gas-air mixtures may be categorised into continuous, primary and secondary grades:

(a) Continuous grades of release include the following:

- (i) The surface of a flammable liquid in a closed tank or pipe.
- (ii) A vent or other opening which releases flammable gases or vapours frequently, continuously or for long periods.

(b) Primary grades of release include the following:

- (i) Pumps and compressors with standard seals, and valves, flanges and fittings containing flammable fluids if release of fluid to atmosphere during normal operation may be expected.
- (ii) Sample points and process equipment drains, which may release flammable fluid to atmosphere during normal operation.
- (iii) Pig launcher and receiver doors, which are opened frequently.
- (iv) Vents which frequently release small quantities, or occasionally release larger quantities, of flammable gases to atmosphere.
- (v) Tanks or openings of the active mud circulating system between the well and the final degasser discharge, which may release gas during normal operation.
- (vi) Drilling operations in enclosed or semi-enclosed spaces, *see Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations*.

(c) Secondary grades of release, include the following:

- (i) Pumps and compressors, and valves, flanges and fittings containing flammable fluids.
- (ii) Vents which release flammable gases intermittently to atmosphere.
- (iii) Tanks or openings of the mud circulating system from the final degasser discharge to the mud pump connection at the mud pit.
- (iv) Drilling, workover and wirelining operations in open spaces, *see Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations*.

1.3 Documentation

1.3.1 Single copies, unless otherwise stated, of the following documentation on 'hazardous areas' are to be submitted for consideration:

- Hazardous area classification philosophy.
- Hazardous area classification design specifications.
- Facility layout plans (plot plans).
- Hazardous area classification schedule (data sheets), *see also Pt 7, Ch 2, 1.3 Documentation 1.3.2*.
- Hazardous area classification plans.

1.3.2 It is expected that the data sheets, referred to in *Pt 7, Ch 2, 1.3 Documentation 1.3.1*, include, but are not limited to, the following information:

- Equipment identification.
- Operating conditions.
- Media and media properties.
- Fluid category.
- Sources of potential release.
- Grades of release.
- Venting rates.
- Hazardous zones determined.
- Dimension of each hazardous zone.
- Code or Standard used for reference.

1.3.3 Single copies, unless otherwise stated, of the following plans and particulars on 'ventilation' are to be submitted for consideration:

- Ventilation design philosophy.
- Ventilation design specifications.
- Ventilation layout plans.
- Ducting and instrumentation plans (D & IDs).

■ *Section 2*
Classification of hazardous areas

2.1 General

2.1.1 The hazardous areas as specified may be extended or restricted depending on conditions such as fluid system pressure and composition, or by the use of structural arrangements such as fire walls, windshields, special ventilation arrangements, etc. For special requirements relating to units intended for the storage of oil in bulk, *see Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*. For special requirements relating to units intended for the storage of liquefied gases in bulk or other hazardous liquids, *see Pt 7, Ch 2, 10 Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk*and *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes* and *Pt 11, Ch 10 Electrical Installations*.

2.1.2 Relatively small non-hazardous areas surrounded by or confined by hazardous areas, or Zone 2 areas within Zone 1 areas, are to be classified as the adjacent surrounding hazardous area.

2.1.3 For gas disposal systems, other than permanently ignited flares, and for vents for large quantities of hydrocarbon gas from production facilities, the classification and extent of the surrounding hazardous areas should be based on dispersion calculations.

2.1.4 For permanently ignited flares, consideration is to be given to possible 'flame out' conditions or intentional periods of cold venting and the hazardous areas created by such are to be determined.

2.1.5 Within these Rules, all reference to the extent of the hazardous zones given as a radius, refers to the horizontal extent of the zone, except where specifically stated as being a spherical zone; for vertical extent of zones, *see Pt 7, Ch 2, 2.5 Vertical extent of hazardous zones*.

2.2 Zone 0

2.2.1 Areas to be classified as Zone 0 include:

(a) The internal space of a closed tank or pipe containing a flammable liquid or gas, crude oil or active mud, or a space where an oil-gas-air mixture is continuously present, or present for long periods;
(b) Unventilated spaces containing a source of release (i.e. flange, valve, etc.) separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas; and
(c) A region around the outlet from non-pressurised tank vents or other sources, or from cold vents where discharge, which releases flammable gases or vapours frequently, continuously or for long periods. The size of this hazardous region should be based on guidance from a recognised Standard (i.e. EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.

2.3 Zone 1

2.3.1 Areas to be classified as Zone 1 include:

(a) Adequately ventilated closed or semi-enclosed spaces containing primary grades of release, *see Pt 7, Ch 2, 1.2 Definitions and categories 1.2.8*;
(b) Mechanically ventilated closed spaces containing a source of release (i.e. flange, valve, etc.) separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas. Or an unventilated closed space not containing any sources of release separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas;
(c) In open spaces, the area surrounding a primary grade of release. The extent of the Zone 1 hazardous area will be based upon the primary grade source of release. The size of this hazardous region should be based on guidance from a recognised Standard (i.e. EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.
(d) In open spaces, the area within 3 m from pig launcher and receiver doors. This may be reduced to 1,5 m if the equipment is washed through with nitrogen or water washed before opening;
(e) In open spaces, the area local to any opening associated with an enclosed Zone 1 area, any ventilation outlet from a Zone 1 space, or any access, such as a doorway or non-bolted hatch to an enclosed Zone 1 hazardous area, is to be classified as a Zone 1 space. The extent of the external Zone 1 hazardous area will be based upon the largest source of release with the enclosed Zone 1 area based on guidance from a recognised Standard (i.e. EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;
(f) Semi-enclosed spaces, such as inadequately ventilated pits, ducts or similar structures situated in locations which would otherwise be a Zone 2, but where their arrangement is such that gas dispersion cannot easily occur.
(g) For units containing drilling facilities, specific reference is to be made to the requirements given in the *Chapter 6 - Machinery and Electrical Installations in Hazardous Areas for All Types of Units*regarding the extent of Zone 1 hazardous areas on MODUs as well as the following *Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations* and the guidance given in EI (formerly IP) Part 15 for drilling facilities.
(h) For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the extent of Zone 1 hazardous areas. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to *Pt 11, Ch 10 Electrical Installations* regarding the extent of the Zone 1 hazardous area.

2.4 Zone 2

2.4.1 Areas to be classified as Zone 2 include:

(a) Adequately ventilated closed or semi-enclosed spaces containing secondary grades of release, *see Pt 7, Ch 2, 1.2 Definitions and categories 1.2.8*
(b) In open spaces, the area beyond the Zone 1 specified in *Pt 7, Ch 2, 2.3 Zone 1 2.3.1* and *Pt 7, Ch 2, 2.3 Zone 1 2.3.1*, and beyond the semi-enclosed space specified in *Pt 7, Ch 2, 2.3 Zone 1 2.3.1*. The extent of the Zone 2 hazardous area will be based upon the primary grade source of release. The extent of the external Zone 2 hazardous area will be based upon the largest source of release with the enclosed Zone 1 area based on guidance from a recognised Standard (i.e. EI (formerly IP)

Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;

(c) In open spaces, the area surrounding a secondary grade of release, any ventilation outlet from a Zone 2 space or any access to a Zone 2 space. The extent of the Zone 2 hazardous area will be based upon the source of release based on guidance from a recognised Standard (i.e. EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;

(d) Mechanically ventilated closed spaces not containing a source of release separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas;

(e) For units containing drilling facilities, specific reference is to be made to the requirements given in the *Chapter 6 - Machinery and Electrical Installations in Hazardous Areas for All Types of Units* regarding the extent of Zone 2 hazardous areas on MODUs as well as the following *Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations* and the guidance given in EI (formerly IP) Part 15 for drilling facilities;

(f) For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the extent of Zone 2 hazardous areas. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to *Pt 11, Ch 10 Electrical Installations* regarding the extent of the Zone 2 hazardous area and;

(g) Air locks between a Zone 1 and a non-hazardous area, *see Pt 7, Ch 2, 4.1 General 4.1.3*; and

(h) For drilling units, specific reference is to be made to the requirements given in the *Chapter 6 - Machinery and Electrical Installations in Hazardous Areas for All Types of Units* regarding the extent of Zone 2 hazardous areas on MODUs, as well as the following *Pt 7, Ch 2, 3 Hazardous areas – Drilling, workover and wirelining operations*.

2.5 Vertical extent of hazardous zones

2.5.1 The relationship between the hazard radius and the full 3-dimensional envelope of the hazardous area is dependent upon the height and orientation of the release and the hazard radius. If the release height and the generated hazardous radius zone are greater than 1 m above the deck, then the developed hazardous area is independent of potential hazardous accumulations of flammable releases at deck level. If the release height and the generated hazard radius are less than 1 m above the deck, then the developed hazardous area is dependent on potential hazardous accumulations of flammable releases at deck level and the subsequent hazardous area needs to take into account the generated hazardous area at deck level. The vertical extent of a hazardous area should be based on guidance from a recognised Standard (i.e. EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.

2.5.2 For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the vertical extent of a hazardous area. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to *Pt 11, Ch 10 Electrical Installations*regarding the vertical extent of a hazardous area.

■ *Section 3*
Hazardous areas – Drilling, workover and wirelining operations

3.1 General

3.1.1 This hazardous area classification applies to any part of the drilling derrick or equipment which could potentially release oil or gas from the well, including equipment that is required to operate under controlled emergency conditions, such as during a blow out.

3.1.2 The requirements of *Pt 7, Ch 2, 2 Classification of hazardous areas*are also to be complied with, where applicable.

3.2 Classification

3.2.1 For units containing drilling facilities, specific reference is to be made to the requirements given in the *Chapter 6 - Machinery and Electrical Installations in Hazardous Areas for All Types of Units* regarding the extent of hazardous areas on MODUs. However, it must be recognised that other recognised Standards (i.e. EI (formerly IP) Part 15) give additional and potentially different hazardous area guidance associated with drill rigs and facilities. As such, the guidance given in these alternative Standards may be more applicable to the drilling facilities associated with the installation to be classified.

Section 4
Enclosed and semi-enclosed spaces with access to a hazardous area

4.1 General

4.1.1 As far as practicable, access doors or other openings should not be provided between a non-hazardous space and a hazardous area or space, or between a Zone 2 space and a Zone 1 space.

4.1.2 Where such openings are necessary, an enclosed or semi-enclosed space with a direct access door or opening leading to an area or space which is of a greater hazard classification is to be regarded as the same hazard classification as the area or space into which this door or opening leads, except where suitable arrangements as permitted by *Pt 7, Ch 2, 4.1 General 4.1.3* are provided.

4.1.3 An enclosed space with direct access to a:

(a) Zone 1 hazardous area may be classified as Zone 2 provided that:
- (i) The access is fitted with a self-closing, gastight door that opens into the Zone 2 space;
- (ii) Ventilation is such that the air flow with the door open is from the enclosed space to the Zone 1 hazardous area; and
- (iii) Loss of ventilation is alarmed at a manned control station.

(b) Zone 2 hazardous area may be classified as non-hazardous provided that:
- (i) The access is fitted with a self-closing, gastight door that opens into the non-hazardous space;
- (ii) Ventilation is such that the air flow with the door open is from the non-hazardous space to the Zone 2 hazardous area; and
- (iii) Loss of ventilation is alarmed at a manned control station.
- (iv) The enclosed space is maintained at an overpressure of at least 50 Pa relative to the external hazardous area.

(c) Zone 1 hazardous area may be classified as non-hazardous provided that:
- (i) The access is via a mechanically ventilated airlock consisting of two self-closing, gastight doors without any hold-back arrangement, and spaced at least 1,5 m but not more than 2,5 m apart;
- (ii) The enclosed space is maintained at an overpressure of at least 50 Pa relative to the external hazardous area; and
- (iii) The relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at a manned control station.

4.1.4 Where one of the doors specified in *Pt 7, Ch 2, 4.1 General 4.1.3* is required to be weathertight or watertight and the provision of a self-closing mechanism would be impracticable, consideration will be given to waiving the requirement for this door to be self-closing, provided the door is normally kept closed and is provided with a notice to this effect.

Section 5
Machinery in hazardous areas

5.1 General

5.1.1 Installation of mechanical equipment within hazardous areas should be limited to that considered to be necessary for operational purposes within that area. Wherever possible, the installation of fired equipment or internal combustion machinery in hazardous areas should be avoided.

5.1.2 Where it is considered necessary for mechanical equipment or machinery to be installed in a hazardous area, it is to be constructed and installed so as to reduce the risk of sparking due to friction between moving parts or the formation of static electricity, or to ignition due to exposed high-temperature exhausts, etc. Electrical equipment shall comply with *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*.

Non-electrical equipment or machinery shall comply with the appropriate parts of EN 13463 Series *Non-electrical equipment for use in potentially explosive atmospheres*', alternatively protection by installation in a pressurised enclosure complying with IEC 60079-2 *Electrical apparatus for explosive atmosphere*.

Engines (Internal combustion engines) shall normally be located in non-hazardous (safe) areas. Where it is considered necessary for internal combustion engines to be located in a Zone 2 hazardous area the engine and installation shall comply with *Pt 7, Ch 2, 7 Engines in hazardous areas* of this Chapter. Engines are not permitted in Zone 0 and Zone 1 hazardous areas on offshore installations.

Where it is considered necessary to install gas turbines in hazardous areas guidance shall be obtained from relevant International or National Standard(s) such as ISO 21789 - *Gas turbine applications – Safety*.

5.1.3 Air compressors are not, in general, to be installed in hazardous areas. However, where this is not practicable, such installation may be accepted provided that the air inlet is from a non-hazardous area in accordance with *Pt 7, Ch 2, 6.4 Location of air intakes and exhausts*, and that the inlet ducting is fitted with suitable gas detectors arranged to give an audible and visual alarm and to shut down the compressor in the event of flammable and/or toxic gases entering the air inlet. Any mechanical equipment or machinery installed in a hazardous area shall comply with *Pt 7, Ch 2, 5.1 General 5.1.2*.

5.1.4 Fans located in hazardous areas are to be of the non-sparking type and comply with EN 14986:2007 *Design of fans working in potentially explosive atmospheres* or alternative relevant *International or National Standard*.

5.1.5 For the requirements appertaining to the installation of suitably protected engines in a Zone 2 hazardous area, *see Pt 7, Ch 2, 7 Engines in hazardous areas*.

5.1.6 Wherever possible, piping system arrangements are to preclude direct communication between hazardous and non-hazardous areas, and between hazardous areas of different classifications. Where pipes, ducts or cables pass through decks or bulkheads, the penetration is to be designed to prevent the passage of hazardous gases.

5.1.7 Maintenance hatches and removable panels are to be provided with suitable seals to prevent the passage of hazardous gases when closed.

5.1.8 When oil storage pumps and ballast pumps in dangerous or hazardous spaces are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by *Pt 7, Ch 2, 5.1 General 5.1.8*, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered. The design of the alarm, control and safety systems is to comply with the requirements of *Pt 6, Ch 1, 2 Essential features for control, alarm and safety systems*. Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could cause hazard.

Table 2.5.1 Alarm and safety arrangements

Item	Alarm	Note
Bulkhead gland temperature	High	Any machinery item
Bearing temperature	High	Any machinery item
Pump casing temperature	High	‘Oil storage’ pumps only
Bilge level	High	
Hydrocarbon concentration	High	>20% LEL

■ *Section 6* **Ventilation**

6.1 General requirements

6.1.1 Mechanical ventilation systems are to be capable of continuous operation by the provision of adequate standby/ redundancy capable of maintaining the required flow rates and pressure differentials. Machinery spaces are, where practicable, to be served by redundant air intake ducts.

6.1.2 Open or semi-enclosed spaces which are designed to be ventilated by natural means are to achieve a minimum of 12 air changes per hour for 95 per cent of the time. This natural ventilation may be augmented by mechanical means.

6.1.3 Non-hazardous enclosed spaces are to be maintained with an overpressure of at least 50 Pa in relation to any adjacent more hazardous areas or spaces. The non-hazardous area ventilation with positive pressurisation is to be designed to help mitigate against potential gas ingress to the non hazardous area so that where there is any doorway, hatch or other opening in the contiguous boundary, the ventilation helps to prevent the transmission of fluids from the more hazardous area or space to the less hazardous space.

6.1.4 Accommodation spaces are to be maintained at a positive pressure in relation to the outside atmosphere.

6.1.5 Ventilation services to drilling utilities areas and to wellhead areas should, where practicable, be separate from services to other hazardous areas.

6.1.6 Air supplied for combustion and/or cooling of engines or other fuel-burning equipment is to be supplied separately from general ventilation services. The ventilation system for engine or boiler rooms is to be independent of all other ventilation systems. Induced draught fans, or a closed system of forced draught may be employed for fired equipment, or the fired equipment may be enclosed in a pressurised air casing.

6.1.7 System design is to be arranged for individual isolation to enable continuity of operation and purging of spaces following contamination.

6.1.8 The system design is to take due regard to the possible weathervaning of the unit and periods when the current is the prevailing factor, such that the air intake, at low wind speeds, may be partially starved of air.

6.1.9 Ducting materials, including associated fittings, are to be of a non-combustible material, to be of all welded construction adequate to withstand likely damage and corrosion and to be suitable for a marine saline atmosphere. Ventilation fans are to have non-overloading, non-stall characteristics and are to be fitted with anti-sparking tracks.

6.1.10 For aspects of ventilation systems relating to fire integrity, *see Pt 7, Ch 3 Fire Safety*, and for gas detection requirements, *see Pt 7, Ch 1, 5 Protection against gas ingress into safe areas*.

6.2 Ventilation of hazardous spaces

6.2.1 Ventilation systems and ducting for spaces designated as hazardous areas are to be entirely separate from ventilation systems and ducting for spaces designated as non-hazardous areas.

6.2.2 All enclosed hazardous spaces are to be adequately ventilated by a mechanical ventilation system providing at least 12 air changes per hour. Air change calculations are to be based upon empty volume of space. The mechanical ventilation is to be such that hazardous enclosed spaces are maintained with an underpressure of at least 50 Pa in relation to any adjacent less hazardous areas or spaces.

6.2.3 To ensure that the required relative underpressure is maintained in any hazardous enclosed space, the supply and exhaust fans are to be interlocked so that the supply fan cannot be run unless the exhaust fan is running.

6.2.4 Ventilation arrangements should ensure that the entire space is adequately ventilated, giving an even air distribution, with special consideration to locations where there is equipment which may release gas, and to locations within the space where stagnant pockets of gas could accumulate.

6.2.5 Electric heating elements are to be fitted with automatic temperature control, a high temperature alarm and an independent sensor and cut-out with manual reset. The surface temperature is to be restricted to a maximum of 200°C, or below the ignition temperature of any flammable gas likely to be present in the area.

6.2.6 The presence of gas within the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. In these circumstances all ventilation equipment must be rated to operate in a Zone 1 hazardous area.

6.3 Ventilation of other spaces containing sources of hazard

6.3.1 Ventilation systems and ducting for any space containing a source of release of a flammable substance, but not designated as a hazardous space in its entirety (e.g. by virtue of compliance with *Pt 7, Ch 2, 1.2 Definitions and categories 1.2.5*), are to be entirely segregated from ventilation systems and ducting for other non-hazardous areas or spaces.

6.3.2 The mechanical ventilation is to be such that the space and ducting serving it is maintained at an underpressure of at least 50 Pa in relation to adjacent non-hazardous areas or spaces.

6.3.3 Where the ventilation air flow rate within the space in relation to the maximum release rate of flammable substances reasonably to be expected under normal operating conditions is sufficient to prevent any concentration of flammable substances approaching their lower explosive limit, consideration will be given to regarding the entire space, including the zone around

equipment contained within it, its ventilation systems and other openings into it, as non-hazardous. Ventilation airflow is to be monitored and appropriate measures taken in the event of failure. For requirements particular to gas turbine rooms and hoods, *see Pt 7, Ch 2, 6.5 Gas turbine ventilation*.

6.3.4 The presence of gas within the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. In these circumstances all ventilation equipment must be rated to operate in a Zone 1 hazardous area.

6.4 Location of air intakes and exhausts

6.4.1 Supply air intakes are to be located in external non-hazardous areas, at least 3 m from the boundary of any hazardous area.

6.4.2 The siting of supply air intakes should be such as to avoid the possibility of drawing in combustion products from equipment exhausts or hazardous/toxic gases from process equipment.

6.4.3 Ventilation intake and outlet ducts should not pass through spaces of different classification. Where this is unavoidable, ducts may pass through a more hazardous space than the ventilated space provided; such ducts have an overpressure in relation to the space through which they pass. Where necessary, ducts should be of welded, gastight construction. The internal space of such ducts is to have the same zone classification as the ventilated space.

6.4.4 Ventilation outlets are, as far as is practicable, to be located in external areas of the same or lesser zone classification as the ventilated space. Where this is not practicable, appropriate measures are to be taken to prevent backflow into the ventilated space, in the event of ventilation failure.

6.4.5 The separation between air intakes and outlets should be at least 4,5 m. The siting of inlets and outlets should be such as to avoid the possibility of cross-contamination.

6.4.6 Ventilation intakes and outlets are to be located and arranged to avoid ingress of rain, snow and sea-water, even under predicted worst storm conditions.

6.4.7 Gas turbine intakes and exhausts are to be positioned well clear of the unit's structure. Turbine exhausts are to be safely located, so as not to endanger personnel or interfere with helicopter operations.

6.4.8 Where practicable, ventilation outlets from non-hazardous areas should not discharge into a hazardous area.

6.4.9 Air intakes for internal combustion engines (unless certified for use in a Zone 2 hazardous area), fired boilers and other fired units are to be located at least 3 m from hazardous areas.

6.5 Gas turbine ventilation

6.5.1 The turbine room is to be designed as a non-hazardous space, mechanically ventilated with at least 12 air changes per hour and arranged so that an overpressure of at least 50 Pa is maintained in relation to the turbine hood.

6.5.2 The turbine hood is to be mechanically ventilated by means of one duty and one 100 per cent stand-by extraction fan with a ventilation rate to remove adequately heat from the turbine and equipment, and to dilute any flammable gas. Potential leakage from under the turbine hood is to be considered. The ventilation rate is to be at least 12 air changes per hour and arranged so that an underpressure of at least 50 Pa is maintained in relation to the turbine room. On failure of the duty fan, an alarm is to be given in the control room and the stand-by fan automatically activated.

6.5.3 Provided it can be shown that no exposed surface of the turbine or equipment inside the hood will have a surface temperature exceeding 200°C, or that the surface temperature will not exceed 80 per cent of the auto-ignition temperature of any flammable gas which may be present, the ventilation rate may be as per *Pt 7, Ch 2, 6.5 Gas turbine ventilation 6.5.2* where the turbine is in operation. Under these conditions, the space inside the hood will be classified as a Zone 2 hazardous area.

6.5.4 Where the surface temperature of the turbine or equipment inside the hood could exceed 80 per cent of the auto-ignition temperature of any flammable gas which may be present, the space inside the hood is to be ventilated with at least 90 air changes per hour. Under these conditions, the turbine hood need not be classified as a hazardous area when the turbine is in operation.

6.5.5 The turbine hood ventilation fans referred to in *Pt 7, Ch 2, 6.5 Gas turbine ventilation 6.5.2* are to be interlocked with the turbine starting sequence, to provide at least five air changes in the turbine hood before start up of the turbine or the energising of any associated electrical equipment, other than that suitable for installation in a Zone 1 location. On shut-down, the duty fan is to purge the turbine hood until the turbine has stopped. At least one of the fans is to be supplied from an emergency power source. *See also Pt 6, Ch 2, 3.7 Alternative sources of emergency electrical power 3.7.9*.

6.5.6 Equipment which is required to remain activated after shut-down or hood ventilation failure, is to be certified for use in a Zone 1 hazardous area.

6.5.7 Gas detectors are to be installed inside the turbine hood to shut down the turbine on detection of gas.

6.5.8 For gas turbines utilising gas fuel from the production and process facility, the arrangement and capacities of the ventilation system and fuel gas piping are to comply, where applicable, with the requirements of*Pt 5, Ch 16 Gas and Crude Oil Burning Systems*, taking into account any additional requirements which may be necessary during start-up or shut-down of the plant.

■ *Section 7* **Engines in hazardous areas**

7.1 Application

7.1.1 Engines are not permitted in Zone 0 and Zone 1 hazardous areas on offshore installations. Engines which are required to operate in Zone 2 hazardous areas are to comply with the requirements of *Pt 7, Ch 2, 7.1 Application 7.1.2* to *Pt 7, Ch 2, 7.1 Application 7.1.23*. National Standards and Government Regulations or Codes of Practice which differ from these requirements may also be accepted, provided an equivalent standard of protection is achieved.

7.1.2 The air induction system is to be provided with a shut-off valve located between the engine air inlet filter and the flame arrester. The valve is to be capable of being closed manually. The valve is also to be capable of being automatically closed by the engine overspeed device and consideration should be given to provision being made so that the induction air valve and engine fuel supply should automatically close by a signal from a local gas sensor.

7.1.3 An approved corrosion resistant flame arrester, constructed and tested to a recognised Standard, is to be provided in the induction system. The flame arrester is to be as close to the engine as possible with good access for inspection and overhaul.

7.1.4 Joints used in the induction and exhaust systems are to be designated either as ‘open joints’ or ‘closed joints’.

7.1.5 An open joint will allow the free passage of gas but will not allow the passage of flame. The dimensions of such a joint are to be determined in accordance with *Pt 7, Ch 2, 7.1 Application 7.1.8*. A flame arrester is a particular type of open joint considered separately by testing.

7.1.6 A closed joint will not allow the passage of either gas or flame under normal or test conditions.

7.1.7 An approved corrosion resistant flame arrester is to be provided in the exhaust system. The flame arrester is to be constructed and tested to a recognised Standard. The flame arrester is to be fitted as close to the engine as possible, with good access for inspection and replacement. The flame arrester can be omitted if the exhaust terminates in a non-hazardous area.

7.1.8 A spark arrester is to be fitted in the exhaust system downstream of the flame arrester. The spark arrester is to be constructed and tested to a recognised Standard.

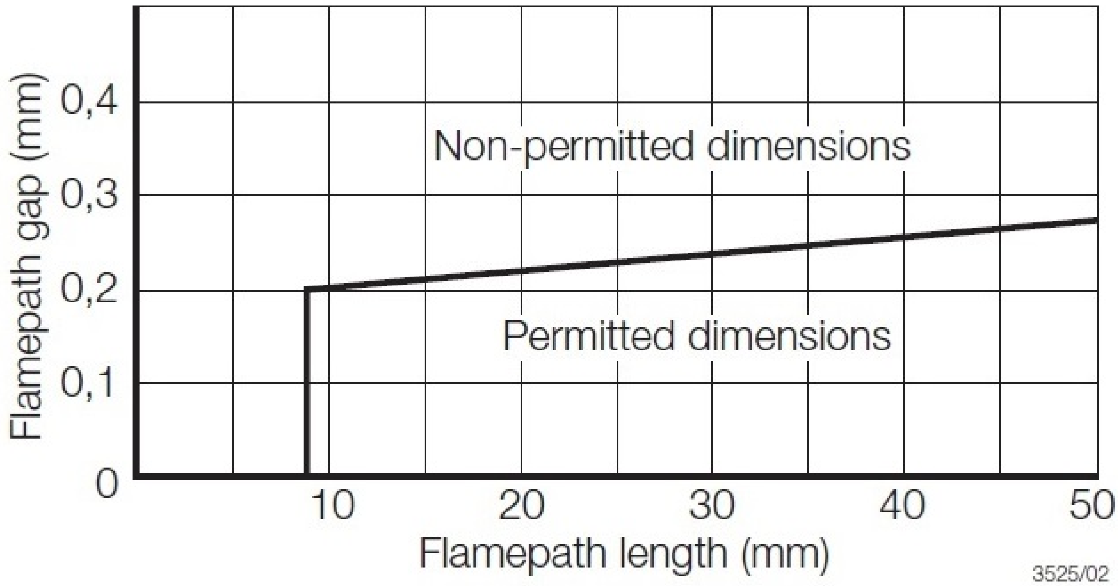


Figure 2.7.1 Relationship between length and gap for flamepaths

7.1.9 Consideration should be given to a back pressure indicator being fitted to the exhaust manifold to provide prior warning of exhaust flame arrester fouling.

7.1.10 The engine crankcase breather pipe is to be fitted with a flame arrester. For engines in enclosed Zone 2 areas, the breather pipe is to be led to the open atmosphere. The breather pipe is not to be led to the engine induction system.

7.1.11 The engine crankcase is to operate at a small positive pressure.

7.1.12 With the engine at maximum continuous rating and temperatures stabilised, no surface temperature on the engine or exhaust system is to exceed 200°C.

7.1.13 Ventilation fan blades and belts are to be of the anti-static type. The combination of materials for fan impellers and the housing are to be non-sparking under both normal and fault conditions.

7.1.14 Engine starting systems are not to introduce a source of ignition external to the engine. The system is to have appropriate safe-type certification, or to be capable of being demonstrated as being of a safe-type by appropriate testing.

7.1.15 The engine is not to be capable of running in reverse.

7.1.16 Fuel supply is to be capable of being shut off manually and automatically in the event of:

- Overspeeding;
- High exhaust temperature, *see Pt 7, Ch 2, 7.1 Application 7.1.17*;
- High cooling water temperature; or
- Low lubricating oil pressure.

7.1.17 The high exhaust temperature sensor is to be located upstream of the exhaust flame arrester. The high exhaust temperature sensor and engine shut-down on high exhaust temperature can be omitted if the exhaust pipe terminates in a safe area.

7.1.18 Basic operating instructions should be permanently attached to the unit giving details of stop, start and emergency procedures.

7.1.19 Where an engine is fitted inside any enclosure, the following requirements are to be complied with, as applicable:

(a) Where an engine is located inside an enclosed Zone 2 hazardous area, the space is to be independently ventilated at a recommended minimum rate of 20 air changes per hour whilst the engine is running and 12 air changes per hour when stopped.

(b) For engines placed inside enclosures of any type, it is recommended that fire and gas sensors be provided inside the enclosure are suitably alarmed to a continuously manned control room.

7.1.20 A hydraulic proof test at a gauge pressure of 5 bar or 1,5 times the maximum pressure obtained in explosion tests in accordance with *Pt 7, Ch 2, 7.1 Application 7.1.21* is to be witnessed on the induction and exhaust system components without showing signs of leakage.

7.1.21 For engines of 370 kW (500 shp) and above, the induction and exhaust systems are to be explosion tested to a recognised Standard without showing signs of damage or flame transmission to the atmosphere. The maximum explosion pressure is to be recorded and used in the hydraulic proof test in *Pt 7, Ch 2, 7.1 Application 7.1.20*.

7.1.22 Complete engine units and driven components are to be examined and tested at the manufacturer's works or other suitable works before being put into service. Thereafter, the complete unit is to be examined annually and the original certificate endorsed or as otherwise agreed to ensure a permanent written record of survey. It is recommended that time clocks of the non-resetting type be fitted to the engine.

7.1.23 Where an engine manufacturer carries out satisfactory type tests on an engine or series of engines and subsequently provides conversion kits for similar engines, proof tests can be waived. However, each converted engine is to be shop tested in accordance with *Pt 7, Ch 2, 7.1 Application 7.1.22*.

■ *Section 8*
Electrical equipment for use in explosive gas atmospheres

8.1 General

8.1.1 The requirements for electrical equipment for use in explosive gas atmospheres are given in *Pt 6, Ch 2, 14.1 General*, *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres* and *Pt 6, Ch 2, 14.9 Cable and cable installation* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which are to be complied with where applicable.

8.1.2 Additional or amended requirements are given in *Pt 7, Ch 2, 8.1 General 8.1.3* to *Pt 7, Ch 2, 8.1 General 8.1.14*.

8.1.3 In locations classified as Zone 0, and in various enclosed spaces identified in Section 9, only intrinsically safe equipment of category 'ia', or simple apparatus as defined in *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.4* of the Rules for Ships and complying in full with the relevant requirements of IEC 60079 for intrinsic safety, category 'ia', is permitted.

8.1.4 In locations classified as Zone 1 and in spaces and locations identified in *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)* as permitting the installation of safe type equipment, other than locations described in *Pt 7, Ch 2, 8.1 General 8.1.5*, only the following equipment may be installed:

- Equipment having a type of protection listed under *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.5* of the Rules for Ships.
- Equipment as described under *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.6* of the Rules for Ships, arranged to be de-energised automatically on loss of pressurisation.

8.1.5 In locations classified as Zone 2, and on open deck in well ventilated positions not within 3 m of any flammable gas or vapour outlet, equipment having the types of protection listed under*Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.5* of the Rules for Ships, or as described under *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.6* to *Pt 6, Ch 2, 14.2 Selection of equipment for use in explosive gas atmospheres 14.2.6*of the Rules for Ships may be installed.

8.1.6 Any electrical equipment which has to remain operational during a Major Accident Event (e.g. rupture of a process vessel or pipe), whether or not installed in a hazardous zone or location, is to be suitable for use in an explosive gas atmosphere. Such equipment is to be of a type permitted within Zone 1 locations, unless it is demonstrated that the equipment is appropriately protected against potentially coming into contact with a flammable atmosphere by being located in an enclosed safe area with

appropriate mitigating measures (i.e. enclosed safe area is equipped with gastight barriers, gastight doors, rated gas dampers, suitable gas detection within the enclosure and its ventilation air intakes, etc.).

8.1.7 Flame-proof enclosures and intrinsically safe electrical apparatus, and apparatus incorporating flame-proof or intrinsically safe components or otherwise tested or certified for particular groups, with reference to the group(s) of gas(es) that may be present, is to be selected with reference to IEC/TR 60079-20: *Electrical apparatus for explosive gas atmospheres – Part 20: Data for flammable gases and vapours*, relating to the use of electrical apparatus.

8.1.8 The electrical apparatus shall be so selected that its maximum surface temperature as indicated by its temperature class, or otherwise documented, will not reach the auto-ignition temperature of any gas or vapour, or mixture of gases or vapour, which can be present. The ambient temperature range for which the apparatus is certified is to be taken to be minus 20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases encountered.

8.1.9 Cables are not permitted to pass through locations classified as Zone 0, and are permitted to enter such locations only where required for the operation of any electrical equipment located therein.

8.1.10 Cables are to be either:

(a) Mineral insulated with copper sheath; or
(b) Armoured or braided, except where:
    (i) The cable is associated with an intrinsically safe circuit; or
    (ii) The cable does not pass into or through any location classified as Zone 1, and is routed or protected so as to present only a low risk of mechanical damage; or
    (iii) A cable of flexible construction is demanded by operational requirements, and its construction, routing and means of support are such as to present only a low risk of mechanical damage; or
    (iv) The cable is installed within a conduit system meeting the relevant requirements of IEC60079-14.

8.1.11 Metal coverings of cables installed in hazardous zones or spaces are to be effectively earthed at both ends, at least, except where otherwise permitted by IEC 60079-14.

8.1.12 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g. neither installed in the same protective casing nor secured by the same fixing clip, except where alternative arrangements are permitted by IEC 60079-14.

8.1.13 No more than one intrinsically safe circuit should be run in any multicore cable unless:

(a) No circuit is required to be of category 'ia', and either:
    (i) The cable is run or protected so as to present little risk of its suffering mechanical damage; or
    (ii) Each intrinsically safe circuit is contained within an earthed metallic screen; or
(b) It can be shown that no combination of faults between the intrinsically safe circuits within the cable can lead to an unsafe condition.

8.1.14 Cabling, wiring, and connections within enclosures containing more than one intrinsically safe circuit, or containing both intrinsically safe and other circuits, are to be arranged in accordance with the relevant requirements of IEC60079-11 and IEC60079-14 so as to minimise the risk of inadvertent interconnections between different circuits.

■ *Section 9*
Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)

9.1 General

9.1.1 The additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test) are given in this Section.

9.1.2 Spaces or locations associated with or close to the arrangements for oil storage, loading and discharging are to be classified into hazardous zones, and electrical equipment is to be selected and installed, in accordance with IEC 60092- 502: *Electrical Installations in Ships – Tankers – Special Features*.

9.1.3 Alternatively, classification of these spaces or locations may be carried out by application of the methods given in IEC Publication 60079-10-1 or EI (formerly IP) Part 15, taking into account the probable frequency, duration and rates of leakages of flammable material from all sources (including structural defects) and the degree and availability of ventilation at the location. The selection and installation of electrical equipment is to meet the requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres* for the relevant zone.

9.1.4 In addition to the requirements of *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*, cables, other than those of intrinsically safe circuits, in hazardous zones or spaces, or which may be exposed to stored oil, oil vapour or gas, are to be either:

(a) mineral insulated with copper sheath; or

(b) armoured or braided (for mechanical protection and earth detection) with non-metallic impervious sheath.

9.1.5 Where electrical equipment is not suitable for a hazardous area into which the space has an opening, the electrical supply to the equipment is to be disconnected, provided shutting down the equipment will not introduce a hazard. In this case, an alarm may be given, in lieu of shutdown, upon loss of overpressure or ventilation, and a means of disconnection of the electrical equipment, capable of being controlled from a manned station, provided in conjunction with an agreed operational procedure. Where the means of disconnection (whether controlled automatically or manually) is located within the space, it is to be equipment of a type suitable for use in a Zone 1 location.

9.1.6 Within any space classified as safe by virtue of pressurisation, any electrical equipment required to operate upon loss of overpressure and lighting fittings and equipment within the air-lock is to be of a type suitable for a Zone 1 location. Means are to be provided to prevent electrical equipment, other than that suitable for a Zone 1 location, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the internal volume of the space.

■ *Section 10*
Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk

10.1 General

10.1.1 *See Pt 11, Ch 10 Electrical Installations*.

■ *Section 11*
Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes

11.1 General

11.1.1 *See Chapter 10* of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk.*

■ *Section 12*
Requirements for units with space for storing paint

12.1 General

12.1.1 The In order to eliminate potential sources of ignition in paint stores, electrical equipment is to be selected as follows:

(a) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a type acceptable for **zone 1**;

(b) electrical equipment situated within 1m of inlet and exhaust ventilation openings or within 3m of exhaust mechanical ventilation outlets is to be of a type acceptable for **zone 2**, or is to have an enclosure of ingress protection rating of at least IP55, *see* IEC 60529, Classification of Degrees of Protection Provided by Enclosures. *See Pt 6, Ch 2, 1.11 Location and construction of equipment 1.11.1* for degrees of protection required for equipment on open deck.

12.1.2 A space having access to a paint store may be regarded as non-hazardous if fulfilling all the following conditions:

(a) access is by means of a self-closing gastight steel door without any hold-back arrangement;
(b) the paint store is ventilated from a non-hazardous area;
(c) warning notices are fitted adjacent to the paint store entrance warning of flammable liquids contained in paint store.

NOTE

A watertight door may be considered as being gastight.

12.1.3 The relevant group and temperature class for electrical equipment in hazardous zones are, respectively, IIB and T3.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for fire and gas detection systems and other safety systems are to be in accordance with *Pt 7, Ch 1 Safety and Communication Systems*. The requirements for hazardous areas and ventilation are to comply with *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

1.1.2 Compliance with the requirements for fire safety of the National Administrations in the area where the unit is located and/or the country in which the unit is registered, is to be demonstrated by the issue of appropriate certification in accordance with *Pt 1, Ch 2, 1.1 Application*.

1.1.3 In addition to the requirements of *Pt 7, Ch 3, 1.1 Application 1.1.1* and *Pt 7, Ch 3, 1.1 Application 1.1.2*, units with production and process plant are to comply with the additional requirements given in *Pt 7, Ch 3, 3 Additional requirements for units with production and process plant*.

1.1.4 Units with crude oil storage tanks are, in general, to comply with the relevant requirements for tankers detailed in *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction* and IMO *International Code for Fire Safety Systems (FSS)* (hereinafter referred to as FSS Code). Where this is not practicable owing to the general construction of the unit, special consideration will be given to other arrangements which provide equivalent protection, *see also Pt 3, Ch 3, 1.4 Installation layout and safety*.

1.1.5 The definitions given in *Pt 7, Ch 3, 2 Definitions* are, in general, in accordance with the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)* (hereinafter referred to as 2009 MODU Code) and are included for reference purposes only. Additional definitions for offshore units are also given. Where applicable, reference to these definitions may be used in other Parts of these Rules.

1.1.6 For units containing drilling facilities, reference should be made to the requirements of the 2009 MODU Code and the requirements of *Pt 3, Ch 7 Drilling Plant Facility* for fire safety and escape and evacuation facilities.

1.1.7 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of *Pt 11, Ch 11 Fire Prevention and Extinction* . It should be noted that *Pt 11, Ch 11 Fire Prevention and Extinction* of these Rules and Regulations reflects the requirements of the *2014 IGC Code - International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* and the associated Lloyd's Register's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2016*

1.2 Submission of documentation

1.2.1 The requirements for submissions of documentation are given in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.7* to *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.10*, which are to be complied with where applicable.

1.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable, as in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.3* to *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.10*.

1.2.3 In addition to the requirements of *Pt 7, Ch 1 Safety and Communication Systems* of these Rules, when Lloyd's Register (LR) is authorised to carry out approvals of fire protection, detection and extinction arrangements on behalf of a National Administration or the requirements of *Pt 1, Ch 2, 1.1 Application* of these Rules are applicable, the plans and documents detailed

below and required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.7*, *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.8*, *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.9* and *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.10* are to be submitted for approval, together with all additional relevant information, such as the intended function of the unit, the gross tonnage and the power of machinery.

1.2.4 The requirements for active and passive type fire protection systems are to be clearly defined within the unit's 'Fire and Explosion Evaluation' (FEE) report, *see Pt 7, Ch 3, 2.4 Fire and Explosion Evaluation (FEE)*, and the requirements for means of escape, evacuation and rescue are to be clearly defined within the unit's 'Escape, Evacuation and Rescue Assessment' (EERA), *see Pt 7, Ch 3, 4.1 General requirements 4.1.2*. Both reports are to be submitted for acceptance and in conjunction with the plans required below.

1.2.5 In the case of units with production and process plant, the FEE Report required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*, which is also supporting the preparation and appraisal of information required in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.8*, *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.9* and *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.10*, and the information required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.7*, are to be submitted for review with full details of the water deluge system and/or water monitor system as required by *Pt 7, Ch 3, 3.4 Water deluge systems, water monitors and foam systems*.

1.2.6 For units with production and process plant, plans of escape routes with details of their protection are to be submitted for acceptance as required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.7*.

1.2.7 For fire protection, the following plans and documents are to be submitted:

- A general arrangement plan showing escape routes, stairways and fire compartmentation bulkheads and decks, including machinery spaces, control stations, accommodation and service spaces, corridor bulkheads and stairway enclosures. This should include details of the location of the defined muster areas, life-saving appliances, Emergency Escape Breathing Devices (EEBDs) and any other Emergency Breathing Apparatus and any defined Temporary Refuge.
- A ventilation plan showing the ducts and any dampers in them, and the position of the controls for stopping the system.
- A plan showing the automatic fire detection and fire alarm system.
- A plan showing the location and arrangement of the emergency stop for the fuel oil unit pumps and for closing the valves on the pipes from oil fuel tanks.
- A plan showing the details of the construction of the fire protection bulkheads, decks and deck heads and the particulars of any surface laminates incorporated in them.
- Copies of the Certificates of Approval by National Authorities in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc. which are intended to be used.
- A general arrangement plan showing the purpose of each room or compartment and the fire classification of the bulkheads, decks, deck heads and doors of the accommodation and service spaces, control rooms and machinery compartments.
- A plan showing the construction of the fire doors.
- A plan showing any proposed remote control system for closing doors.
- A plan showing any proposed water sprinkler system.
- A plan showing the location and arrangement of the emergency stop for the fuel oil unit pumps and for closing valves on the pipes from fuel oil tanks.
- A plan of any proposed gas detection and alarm system.

1.2.8 For fire-extinguishing, the following plans and particulars are to be submitted:

- A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials and the cross-connections to any other system.
- A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.
- A general arrangement plan showing the disposition of all the fire-fighting equipment, including the water fire main, all fixed fire-extinguishing systems, the disposition of all portable and non-portable extinguishers and the types used and the position and details of the fireman's outfits and any helicopter crash kits.
- A plan showing the layout and construction of hydrants, hoses and nozzles including their material and type and the international shore connections.

1.2.9 For fire-control, general arrangement plans are to be submitted:

(a) showing clearly for each deck:

- The control stations;

- The various fire sections enclosed by ‘H’ Class divisions, *see Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.2*;
- The various fire sections enclosed by ‘A’ Class divisions, *see Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.1*; and
- The fire sections enclosed by ‘B’ Class divisions, *see Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.3*;

(b) together with particulars of the:

- Fire alarms;
- Detecting systems;
- Sprinkler/deluge systems (if any);
- Fire-extinguishing appliances;
- Means of access to different compartments, decks, etc.; and
- Ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each fire section.

1.2.10 The general arrangement plans, as required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.9*, are to be permanently exhibited in all units, for the guidance of those on board:

(a) Alternatively, the aforementioned details may be set out in a booklet, a copy of which is to be supplied to each responsible person, and one copy at all times is to be kept up to date, any alterations being recorded thereon as soon as practicable.
(b) All descriptions in such plans and booklets are to be in the official language of the Flag State. If the language is neither English nor French, a translation into one of those languages is to be included.
(c) In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

■ *Section 2* **Definitions**

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an acceptable test procedure (*see 2010 FTP Code – International Code for Application of Fire Test Procedures, 20101 – Resolution MSC.307(88)*. Any other material is a ‘combustible material’.

2.1.2 **Steel or other equivalent material**. Where the words ‘steel or other equivalent material’ occur, ‘equivalent material’ means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.2 Fire test

2.2.1 A **standard fire test** is one in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The specimen is to have an exposed surface of not less than 4,65 m^2 and height (or length of deck) of 2,44 m resembling as closely as possible the intended construction and including where appropriate at least one joint. The standard time-temperature curve is defined by a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

at the end of the first 5 minutes	576°C
at the end of the first 10 minutes	679°C
at the end of the first 15 minutes	738°C
at the end of the first 30 minutes	841°C
at the end of the first 60 minutes	945°C

2.2.2 A hydrocarbon fire test is one in which the specimens defined for a standard fire test are exposed in a test furnace to temperatures corresponding approximately to a time temperature curve relating to, and defined by, a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

at the end of the first 3 minutes	880°C
at the end of the first 5 minutes	945°C
at the end of the first 10 minutes	1032°C
at the end of the first 15 minutes	1071°C
at the end of the first 30 minutes	1098°C
at the end of the first 60 minutes	1100°C

2.2.3 A **jet-fire test** is used to determine how effective the passive fire protection materials are in withstanding an actual jet fire. Reference should be made to ISO 22899-1 with regard to jet-fire testing arrangements and defined jet-fire ratings.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure (*see 2010 FTP Code – International Code for Application of Fire Test Procedures, 20101 – Resolution MSC.307(88)*.

2.4 Fire and Explosion Evaluation (FEE)

2.4.1 The FEE is an assessment of the potential fire loadings and blast pressures, based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints.

2.4.2 These Rules allow for the dimensioning of explosion loads to be based on probabilistic risk assessment techniques. A methodology to establish risk-based explosion loads based on such a probabilistic approach is given in LR's *Guidance Notes for the Calculation of Probabilistic Explosion Loads*.

2.4.3 Important parts of the FEE are the types of fires likely to occur on the offshore unit, the dimensioning of fire loads, fire protection principles, fire mitigation measures and fire response. To assist in developing the FEE, information covering these aspects are provided in LR's *Guidance Notes for Fire Loadings and Protection*.

2.5 Temporary refuge

2.5.1 This is a designated area that is to provide adequate facilities to protect the personnel from fire, explosion and associated hazards during the period for which they may need to remain on a unit following an uncontrolled incident, and for enabling their evacuation, escape and rescue. It is also to provide adequate facilities for monitoring and control of any major incident.

2.6 Fire divisions, spaces and equipment

2.6.1 **'A' Class divisions** are those divisions formed by bulkheads and decks which comply with the following:

(a) They are to be constructed of steel or other equivalent material.
(b) They are to be suitably stiffened.
(c) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test.
(d) They are to be insulated with approved noncombustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A–60'	60 minutes
Class 'A–30'	30 minutes
Class 'A–15'	15 minutes
Class 'A–0'	0 minutes.

(e) A test of a prototype bulkhead or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of *3.2 Use of combustible materials*.

2.6.2 **'H' Class divisions** are those divisions formed by fire walls and decks which comply with the construction and integrity requirements for 'A' Class divisions, *Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.1* and *Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.1* and with the following:

(a) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour hydrocarbon fire test. (Note that some administrations may require the 'H' Class division integrity to be maintained for 120 minutes).
(b) They are to be insulated with approved noncombustible materials, such that the average temperature, on the unexposed side, when exposed to a hydrocarbon fire test, will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180°C above the original temperature within the time listed below:

Class 'H–120'	120 minutes
Class 'H–60'	60 minutes
Class 'H–0'	0 minutes

(c) A test of a prototype fire wall or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.6.3 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following:

(a) They are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test.
(b) They are to have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B–15'	15 minutes
Class 'B–0'	0 minutes

(c) They are to be constructed of approved noncombustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible.
(d) A test of a prototype division may be required to ensure that it meets the above requirements for integrity and temperature rise.

Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

2.6.4 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame, nor limitations relative to the temperature rise. Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

2.6.5 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division. Such linings and ceilings may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

2.6.6 **Machinery spaces of Category 'A'** are those spaces and trunks to such spaces which contain:

(a) Internal combustion machinery used for main propulsion; or
(b) Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) Any oil-fired boiler or fuel oil unit.

2.6.7 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

2.6.8 **Control stations** are those spaces in which the unit's radio or main navigating equipment is located or where the fire-control equipment or the dynamic positioning control system is centralised or process control equipment or where a fire-extinguishing system serving various locations is situated or, in the case of column-stabilised units, a centralised ballast control station is situated.

2.6.9 For definitions and categories of hazardous areas including 'enclosed' and 'semi-enclosed' spaces, *see Pt 7, Ch 2, 1.2 Definitions and categories*.

2.6.10 **Drilling and process plant and industrial machinery and components** are the machinery and components which are used in connection with the operation of drilling, production and process systems.

2.6.11 **Working spaces** are those open or enclosed spaces containing equipment and processes which are not included in *Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.6* or *Pt 7, Ch 3, 2.6 Fire divisions, spaces and equipment 2.6.7*

2.6.12 **Accommodation spaces** are those used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces. 'Public spaces' are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2.6.13 **Service spaces** are those used for galleys, pantries containing cooking appliances, lockers and storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.6.14 **Fuel oil unit** is the equipment used for the preparation of fuel oil for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar.

2.6.15 **Crude oil** is any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes:

(a) Crude oil from which certain distillate fractions may have been removed; and
(b) Crude oil to which certain distillate fractions may have been added.

2.6.16 **Storage spaces** are spaces used for bulk storage and trunks to such spaces, e.g. crude oil storage tanks on oil storage units.

■ *Section 3*
Additional requirements for units with production and process plant

3.1 General requirements for fire-water mains and pumps

3.1.1 Each unit is to be provided with a pressurised wet pipe fire main so equipped and arranged such that water for fire-fighting purposes can be supplied to any part of the unit. The fire main is to be:

(a) Connected to at least two independent fire pumping units, adequately segregated such that a single incident will not compromise the required fire-water supply, as defined in the unit's FEE Report. Each pumping unit is to be capable of providing sufficient fire-water to satisfy the maximum credible fire-water demand. Also refer to *Pt 7, Ch 3, 3.3 Fire pumps 3.3.10* with regards to firewater pump redundancy.
(b) Designed to deliver the pressure and flow requirements for the simultaneous operation of water-based active fire protection systems (deluge waterspray, monitors, hoses, etc.) sufficient to meet the requirements of these systems as defined in the FEE Report. This is typically to be the single largest credible fire area (where deluge/waterspray systems are installed), plus any anticipated manual fire fighting demand (monitors/hose streams).
(c) Where required in the FEE Report, the total fire pumping capability is also to cater for fire escalating to adjacent areas, i.e. typically where suitable fire divisional barriers do not exist.
(d) Capable of delivering at least one jet simultaneously from each of any two fire hydrants, hoses and 19 mm nozzles, while maintaining a minimum pressure of 3,5 bar at any hydrant. In addition, where a foam system is provided for protection of the helicopter deck and is served by the fire main, a pressure of 7 bar at the foam installation is to be capable of being simultaneously maintained.

3.1.2 The arrangements of the pumps, sea suctions and sources of power are to be such as to ensure that a fire in any one space would not put more than one required pumping unit out of action. There are to be at least two water supply sources (sea chests, valves, strainers and pipes, firewater pump risers directly from the sea) provided and so arranged that one supply source

failure will not put all supply sources out of action dependent upon the requirements of *Pt 7, Ch 3, 3.3 Fire pumps 3.3.10* with regards to firewater pump redundancy.

3.1.3 Suitable provision is to be made for the automatic start-up of the fire pumps, when any fire-fighting appliance supplied with water from the fire main is operated. Provision is also to be made for the start-up of the pumps locally and remotely from a continuously manned space or fire-control station. Once activated the pumps are to be capable of continuous unattended operation for at least 18 hours.

3.1.4 For self-elevating mobile offshore drilling units, the following additional fire water supply measures are to be provided:

(a) Water is to be supplied from sea water main filled by at least two submersible pumping systems. One system failure will not put the other system(s) out of function, and
(b) Water is to be supplied from drill water system while unit lifting or lowering. Water stored in the drill water tank(s) is not less than 40 m^3 plus engine cooling water consumptions before unit lifting or lowering. Alternatively, water may be supplied from buffer tank(s) in which sea water stored is not less the quantity as the above mentioned.

3.2 Fire mains

3.2.1 The diameter of any fire-water main and individual service pipes is to be sufficient for the effective distribution of the maximum required discharge from the required pumps operating simultaneously.

3.2.2 With the required pumps operating simultaneously, the pressure maintained in a fire-water main is to be adequate for the safe and efficient operation of all equipment supplied therefrom. The arrangements are to be such that the handheld fire-fighting equipment supplied from the main may be safely used by one person.

3.2.3 Where practicable, fire-water mains are to be routed clear of hazardous areas and be arranged in such a manner as to make maximum use of any thermal shielding or physical protection afforded by the structure of the offshore installation or unit.

3.2.4 Fire-water mains are to be provided with isolating valves, located so as to permit optimum utilisation of the main in the event of physical damage to any part of the main.

3.2.5 Fire-water mains are not to have connections other than those necessary for fire-fighting purposes.

3.2.6 Where applicable, all practicable precautions consistent with having water readily available are to be taken to protect the fire main against freezing.

3.2.7 Materials readily rendered ineffective by heat, are not to be used for fire-water mains unless adequately protected. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them.

3.3 Fire pumps

3.3.1 Any diesel-driven power source is to be capable of being readily started in its cold condition down to a temperature of 0°C, except where agreed otherwise with LR. If this is impracticable, or if lower temperatures are likely to be encountered, consideration will be given to the provision and maintenance of heating arrangements, so that ready starting will be assured. The engine is to be equipped with an approved starting device (e.g. starting battery), independent hydraulic system, or independent starting air system, having a capacity sufficient for at least six starts of the emergency fire pump within a 30 minute period with at least two starts within the first 10 minutes.

3.3.2 Any service fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 18 hours.

3.3.3 Under both normal and emergency conditions any compartment in which a pump unit is located is to be accessible, properly illuminated and efficiently ventilated.

3.3.4 Every centrifugal pump which is connected to a fire water main is to be fitted with a non-return valve.

3.3.5 Relief valves are to be provided in conjunction with all pumps connected to a fire-water main if the pumps are capable of developing a pressure exceeding the design pressure of the main, hydrants and hoses or other fire-fighting equipment connected to the main. Such valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire-water main system.

3.3.6 Means are to be provided for testing the output capacity of each fire pumping unit, in accordance with NFPA (20) or an equivalent Standard.

3.3.7 The provision of surge relief devices is also to be considered at the fire pumps, to prevent over-pressurisation of the mains on fire pump start-up. Such devices are to reset automatically once the excess pressure has been relieved.

3.3.8 The fire-water pump stop should be local only. Except during testing, any alarms from pump-monitoring systems should not automatically stop a running fire pump with the exception of engine overspeed for fire-water pump engine drive units. Fire detection at the fire-water pump should not stop the pump or inhibit the start of the fire-water pump driver. Confirmed hydrocarbon detection in the air inlet of the driver should inhibit the pump start but should not trip a running fire-water pump.

3.3.9 With reference to *Pt 7, Ch 3, 3.3 Fire pumps 3.3.8*, the design of the fire-water pump drive system shall ensure, so far as practical, that the fire-water pump drive set does not constitute an ignition source for potential hydrocarbon gas which may migrate to the pump drive enclosure on a hydrocarbon release incident. As such, the fire-water pump drives should be located in a non-hazardous area of the installation or unit and housed in a non-hazardous enclosure with ventilation designed to be maintained at an overpressure of at least 50 Pa in relation to adjacent external spaces. The fire-water pump drive enclosure is to be constructed with suitable fire-rated and gastight barriers, suitable fire-rated and gastight doors, and suitable fire-rated and gas-rated dampers. The design of the fire-water pump drive is to be such that, on gas detection on the enclosure ventilation air intakes, the drive is capable of continued operation with the enclosure ventilation shut down, ventilation fire and gas dampers closed and all entrances to the enclosure closed.

3.3.10 The installation design should incorporate a suitable allowance for fire-water pump redundancy. This redundancy is to allow for failure of a fire-water pump on demand or loss of a fire-water pump for maintenance without incurring potential lost production on the installation due to the loss of fire-water supply. Permanently manned hydrocarbon installations and mobile offshore drilling units typically have two 100 per cent or three 50 per cent fire-water pumps designed to meet the installation's defined largest credible fire-water demand scenario (i.e. the installation's 100 per cent fire-water demand). However, other configurations of fire-water pump supply redundancy may be acceptable for an installation, subject to suitable demonstration (for example, normally unmanned installations often do not have any dedicated fire-water pumps). For mobile offshore drilling units, reference also needs to be made to the various requirements within the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26) Chapter 9 - Fire Safety*.

3.4 Water deluge systems, water monitors and foam systems

3.4.1 The topside area of each installation or unit is to be provided with a water deluge system and/or water monitor system by means of which any part of the installation or unit containing equipment used for storing, conveying or processing hydrocarbon resources (other than fuels for use on the unit) can be protected in the event of fire. Areas containing equipment requiring water protection include the following:

- Any drilling facilities including the BOP.
- Areas containing equipment, (including piping) through which hydrocarbons will flow during well test operations.
- Crude oil and gas manifolds/piping (not fuel gas), including piping routed over bridges between platforms.
- Crude oil pumps.
- Crude oil storage vessels.
- De-aeration/filtration equipment (if using gas).
- Emergency shut-down valves.
- Flare knockout drums.
- Gas compressors.
- Gas liquids/condensate storage vessels.
- Glycol regeneration plant.
- Liquefaction plant.
- Pig launchers/receivers.
- Process pressure vessels.
- Process separation equipment.
- Riser connections.
- Swivel stack areas.
- Turret areas.

3.4.2 Water deluge systems and water monitors are to be connected to a continuously pressurised water main supplied by at least two pumps, capable, with any one pump out of action, of maintaining a supply of water at a pressure sufficient to enable the system or monitors to operate at the required discharge rates to meet the water demand of the largest single area requiring protection in accordance with the FEE.

3.4.3 The quantity of water supplied to any part of the production and process plant facility is to be at least sufficient to provide exposure protection to the relevant equipment within that part, and where appropriate, local principal load-bearing

structural members. 'Exposure protection' means the application of water spray to equipment or structural members to limit absorption of heat to a level which will reduce the possibility of failure.

3.4.4 Generally, the minimum water application rate is to be not less than 10 litres/minute over each square metre of exposed surface area requiring protection within the appropriate reference area. Other water application rates in accordance with a recognised Standard or Code which meets the requirements of *Pt 7, Ch 3, 3.2 Fire mains 3.2.1* will be considered. The defined water application rates should be established based on a recognised National or International Standard (*see* ISO 13702 or IMO FSS Code). For mobile offshore drilling units reference also needs to be made to the requirements of 3.4.11 with regards to firewater application rates. A reference area is a horizontal area bounded completely by:

(a) Vertical 'A' or 'H' Class divisions; or
(b) The outboard extremities of the unit; or
(c) A combination of (a) or (b).

3.4.5 Each part requiring water protection is to be provided with a primary means of application, which may be:

(a) A fixed system of piping fitted with suitable spray nozzles; or
(b) Water monitors; or
(c) A combination of (a) and (b).

NOTE

Water monitors may only be used for the protection of equipment sited in essentially open areas.

3.4.6 The layout of piping and nozzles within each reference area is to be such that all parts requiring protection are exposed to the direct impingement of water spray. The piping system may be sub-divided within each reference area in accordance with the disposition of equipment and structure.

(a) Spray nozzles are to be of the open type and fitted with deflector plates or equivalent devices capable of reducing the water discharge to a suitable droplet size. The relative location and orientation of individual nozzles is to be in keeping with their established discharge characteristics.
(b) The water pressure available at the inlet to a system or an individual section is to be sufficient to ensure efficient operation of all nozzles in the system or section.

3.4.7 Water monitors may be operated either remotely or locally. Each monitor arranged solely for local operation is to be:

- Provided with an access route which is remote from the part requiring protection; and
- Sited so as to afford maximum protection to the Operator from the effects of radiant heat.

Each monitor is to have sufficient movement in the horizontal and vertical planes to permit the monitor to be brought to bear on any part protected by it. Means are to be provided to lock the monitor in any position. Each monitor is to be capable of discharging under jet and spray conditions.

3.4.8 Any additional requirements for foam type fire protection systems to the topsides process modules and associated plant are to be evaluated within the unit's FEE Report. The specific requirements for foam systems are to be designed to provide extinguishing capabilities in areas where hydrocarbon pool fires may occur. Consideration shall also be given to bunding/drainage arrangements in these areas to ensure that system functionality is not compromised due to lack of hydrocarbon containment.

3.4.9 With regard to the performance requirements for foam systems (concentration levels, discharge time, method of induction, etc.), particular attention is to be given to the design criteria outlined in NFPA 16 or reference is to be made to an acceptable equivalent standard.

3.4.10 With reference to the above requirements for water deluge and water monitor coverage, it may be possible to utilise passive fire protection in place of fire-water cover over certain facilities dependent upon the finding of the FEE, *see Pt 7, Ch 3, 3.6 Passive fire protection*.

3.4.11 Fixed fire extinguishing systems on drilling areas on mobile offshore drilling units should be provided with:

(a) A fixed water spray system to provide protect to the drilling area (drill floor). The minimum water application rate is not less than 20.4 l/min·m2, or
(b) At least two dual-purpose (jet/spray) fire monitors are to be installed to cover drilling and well test areas. The minimum capacity of each monitor is not less than 100m3/h. The monitors may be operated either remotely or locally. Monitors arranged for local operation should be sited on an accessible protected position.

3.4.12 Fixed fire extinguishing systems on a mobile offshore drilling units mud processing area for active mud (i.e. mud mixed with hydrocarbon reservoir fluid) or mud capable of generating a pool fire risk is to consist of a suitable deluge / foam system. The

fixed deluge / foam system is to be capable of delivering foam solution at a rate of at least 10 litres / minute over each square metre of exposed surface requiring protection (via solution made up from either Aqueous Film Forming Foam or Film-Forming Fluoroprotein Foam) for 15 minutes application. Alternatively, a gas fixed fire extinguishing system may be used for enclosed mud processing spaces with a determined pool fire risk.

3.5 Hydrants, hoses and nozzles

3.5.1 The number and position of the hydrants are to be such that at least two jets of water, not emanating from the same hydrant, one of which is to be from a single length of fire hose, may reach any part of the installation or unit normally accessible to those on board. A hose is to be provided for every hydrant.

3.5.2 A cock or valve is to be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are operational.

3.5.3 Fire hoses are to be of type approved material and be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length in general is not to exceed 18 m. Every fire hose is to be provided with a nozzle and the necessary couplings. Fire hoses together with any necessary fittings and tools are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

3.5.4 Standard nozzle sizes are to be 12 mm, 16 mm and 19 mm or as near thereto as possible. Larger diameter nozzles may be permitted if required as a result of special considerations.

3.5.5 For exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure specified in *Pt 7, Ch 3, 3.1 General requirements for fire-water mains and pumps 3.1.1* provided that a nozzle size greater than 19 mm need not be used.

3.5.6 The jet throw at any nozzle is to be about 12 m.

3.5.7 All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.5.8 Mobile Offshore drilling units should be provided with at least one international shore connection complying with *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*and the *FSS Code - Fire Safety Systems – Resolution MSC. 98(73)*. Facilities should be available enabling such a connection to be used on any side of the unit.

3.6 Passive fire protection

3.6.1 As outlined in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.1*, *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.2* and *Pt 7, Ch 3, 3.4 Water deluge systems, water monitors and foam systems 3.4.10*, the additional requirements for passive type fire protection systems to the topsides process modules and associated plant are to be evaluated within the unit's FEE Report. The specific requirements for passive fire protection (PFP) systems are to be designed to provide adequate hydrocarbon containment to prevent escalation and enable safe evacuation of personnel to the 'Temporary Refuge'.

3.6.2 With regard to the performance requirements for PFP systems, particular attention is to be given to the potential thermal and erosive effects of hydrocarbon jet-fires in the initial phase of a topsides incident. Consideration is also to be given to the ongoing thermal effects from pool fires. The duration of these events is to be examined in the project FEE in conjunction with the process system blowdown capabilities.

3.7 Other fixed fire-extinguishing systems

3.7.1 Where included and assessed in the FEE Report (*see Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*) additional consideration will be given to the installation of other fixed fire-extinguishing systems (which may include, but may not be limited to, Fixed Pressure Water Spraying and Water-Mist fire-extinguishing systems, High Expansion Foam systems, Clean Agent fire-extinguishing systems) within internal machinery spaces, accommodation and service spaces, such as cabins and low risk areas. Specific functionality requirements for these systems should be evaluated and clearly defined within the FEE Report.

3.7.2 With regard to the performance requirements for Fixed Pressure Water Spraying and Water-Mist fire-extinguishing systems, particular attention should be given to the requirements of *Chapter 7 - Fixed Pressure Water-Spraying and Water-Mist Fire-Extinguishing Systems* and *Chapter 8 - Automatic Sprinkler, Fire Detection and Fire Alarm Systems* respectively, and of testing standards referred to therein. Reference can also be made to an acceptable equivalent standard (such as NFPA 750) for project-specific applications.

3.8 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities

3.8.1 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of *Chapter 11 Fire Protection and Fire Extinction*of the IMO *International Code for the construction and Equipment of Ships carrying Liquefied Gases in Bulk* (IGC Code) and *Chapter 11* of the associated LR's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*. However, specific reference is to be made to the requirement stipulated within *Pt 11, Ch 11 Fire Prevention and Extinction* .

3.9 Helicopter facilities

3.9.1 Fire fighting facilities for helidecks and any helicopter refuelling equipment should be in compliance with a recognised standard (i.e. UK CAA CAP 437 or *SOLAS - International Convention for the Safety of Life at Sea Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*, *Part G - Special requirements*, *Regulation 18 - Helicopter facilities*). For mobile offshore drilling units reference also needs to be made to the various requirements within the *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26)Chapter 9 - Fire Safety* for fire fighting facilities.

3.9.2 At least one fire extinguisher on the helideck should be a gaseous agent type provided with a suitable applicator for use on engine fires.

■ *Section 4*
Means of escape, evacuation and rescue

4.1 General requirements

4.1.1 For the general requirements for means of escape, *see Part D - Escape*, *Chapter III - Life-saving appliances and arrangements* and *LSA Code - International Life-Saving Appliance Code – Resolution MSC.48(66)* . For units with drilling facilities, *see also* the requirements of *2009 MODU Code - Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009 – Resolution A.1023(26) 9.4 Means of escape*, *9.6 Emergency escape breathing devices* and *Chapter 10 - Life-Saving Appliances and Equipment*

4.1.2 Escape ways on units with production and process plant are to be adequately protected against potential fire loadings emanating from the topside plant and production facilities. The following objectives are to be considered when evaluating the unit's requirements for escape, evacuation and rescue, as also required to be detailed in the Escape, Evacuation and Rescue Assessment (EERA), referred to in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*:

- To maintain the safety of all personnel when they move to another location to avoid the effects of a hazardous event.
- To provide a refuge on the unit for as long as required to enable a controlled evacuation of the unit.
- To facilitate recovery of injured personnel.
- To ensure safe abandonment of the installation or unit.

4.1.3 Where sufficient physical barriers do not exist, escape ways are to be protected by way of active (deluge cooling) or passive (fire screen) type systems.

4.1.4 Escape route widths are to be considered with relation to the number of personnel and individual occupancy of all topsides process and turret areas. Escape routes are to be provided to enable all personnel to evacuate an area safely, when they are directly affected by an incident.

4.1.5 In general, main escape ways from major process and production areas are to have a minimum clear width of 1000 mm, to enable the safe passage of potentially injured personnel (i.e. stretcher evacuees).

4.2 Respiratory protection equipment for hydrogen sulphide risk

4.2.1 For units with an identified hydrogen sulphide risk, in working areas where a high hydrogen sulphide risk may be encountered self-contained breathing apparatus (SCBA) positive-pressure/pressure-demand breathing equipment is to be provided. The SCBA units will provide full-face masks. The SCBA units will be rated for a minimum of 30 minutes supply for each person in the high hydrogen sulphide risk working areas.

4.2.2 For units with an identified hydrogen sulphide risk but outwith working areas where a high hydrogen sulphide risk may be encountered, each person is to be provided with a SCBA rated for a minimum of 15 minutes. Alternatively a positive-pressure/ pressure-demand air line breathing equipment coupled with a SCBA equipped low pressure warning alarm and rated for a minimum of 15 minutes is to be provided for each person on board the unit.

Breathing air supply line stations are to be provided at least in the following areas:

(a) Living quarter;
(b) Muster/evacuation area;
(c) Drilling areas;
(d) Mud processing areas; and
(e) Other working areas.

■ *Section 5*
Deckhouses and superstructures used for accommodation, ‘temporary refuge’ or ‘alternative/secondary refuge or shelter’

5.1 Boundary bulkheads

5.1.1 Particular consideration is to be given to the potential effects of fire and blast, as determined in the unit’s ‘Fire and Explosion Evaluation’ (FEE) report required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*, impinging on exposed boundary bulkheads of accommodation spaces, ‘temporary refuge’ or ‘alternative/secondary refuge or shelter’. Where boundary bulkheads can be subjected to blast loading the scantlings are to comply with *Pt 4, Ch 3, 4.16 Accidental loads 4.16.8* and *Pt 4, Ch 4, 1.10 Topside structure*.

5.2 Safety critical requirements for enclosed spaces

5.2.1 In addition to the requirements of *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*, enclosed spaces of deckhouses and superstructures used for accommodation and/or ‘temporary refuge’ or ‘alternative/secondary refuge or shelter’ are to be at an overpressure relative to the external area to prevent the potential ingress of smoke and hazardous gases, in the event of a major topsides incident.

5.2.2 With reference to *Pt 7, Ch 3, 5.2 Safety critical requirements for enclosed spaces 5.2.1*, the design of the accommodation, 'temporary refuge' and ‘alternative/ secondary refuge or shelter’ is to be such that their enclosures are supplied with a ventilation system designed to maintain an overpressure of at least 50 Pa in relation to adjacent external spaces. The ventilation air intakes to any such enclosure are to be equipped with suitable hydrocarbon gas, smoke and/or toxic gas detection, dependent upon the credible risks associated with the installation or unit. The enclosures are to be constructed with suitable fire-rated and gastight barriers, suitable fire-rated and gastight doors, and suitable fire-rated and gas-rated dampers. The design of the enclosures is to be such that, on hydrocarbon gas, smoke and/or toxic gas detection at the enclosure ventilation air intakes, dependent upon the credible risks associated with the installation or unit, the enclosure ventilation system will shut down and all ventilation fire and gas dampers will close in order to mitigate against potential hydrocarbon gas, smoke and/or toxic gas entering the accommodation, 'temporary refuge' or ‘alternative/secondary refuge or shelter’. Dependent upon the design of the accommodation, ‘temporary refuge’ or ‘alternative/secondary refuge or shelter’ ventilation system, consideration should be given to retain a recirculation ventilation system or an alternative air supply to such enclosures on hydrocarbon gas, smoke and or/toxic gas detection at the enclosure ventilation air intakes. However, it should be ensured that the integrity of the enclosures is not impaired by continued operation of any ventilation system in this scenario.

5.2.3 An endurance period for the ‘temporary refuge’ should be defined in accordance with the escape, evacuation and rescue philosophy for the installation or unit, and appropriate facilities for life support within them should be provided, which should include, but may not be limited to, the following:

- Lighting.
- Means of internal and external communication.
- Means of controlling and monitoring the installation or unit safety systems’.

Design of the ‘temporary refuge’ has also to ensure an appropriate environment for personnel mustering at the location, and for that purpose consideration should be given to criteria such as oxygen depletion, CO2 build-up and temperature build-up.

Information relevant to any such system can be provided as part of the ‘Escape, Evacuation and Rescue Assessment’ (EERA) required by *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*.

5.2.4 With reference to *Pt 7, Ch 3, 5.2 Safety critical requirements for enclosed spaces 5.2.2*, the design of the accommodation ‘temporary refuge' or ‘alternative/secondary refuge or shelter’ enclosure is to include a suitable air leakage rate to mitigate against any potential hydrocarbon gas, smoke and/or toxic gas impairment on isolation of the accommodation, ‘temporary refuge’ or ‘alternative/secondary refuge or shelter’ enclosure ventilation. The air leakage rate should be based on the required endurance period of the accommodation, 'temporary refuge' or ‘alternative/secondary refuge or shelter’ in any potential credible hydrocarbon gas, smoke and/or toxic gas incident associated with the installation or unit.

5.2.5 When the escape, evacuation and rescue philosophy for the installation or unit, or the ‘Escape, Evacuation and Rescue Assessment’ (EERA), referred to in *Pt 7, Ch 3, 1.2 Submission of documentation 1.2.4*, require an alternative or a secondary refuge/shelter, it should be demonstrated that any such refuge/shelter provides appropriate levels of protection and evacuation facilities (including personal protective equipment and personal lifesaving appliances, as applicable) for personnel mustering at those locations, as defined in the EERA.

5.3 Access doors

5.3.1 Access doors to spaces referred in *Pt 7, Ch 3, 5.2 Safety critical requirements for enclosed spaces 5.2.1* are to be fitted with self-closing gastight doors that open outwards from the enclosed space. Special consideration will be given to spaces which are protected by mechanically ventilated air locks, *see also Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

Contents Part 8

■ *Section 1* Corrosion protection

1.1 Application

1.1.1 The requirements cover the corrosion protection of offshore units of the general types defined in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations see also Pt 3, Ch 1 General Requirements for Offshore Units*. Requirements are also given for riser systems, *see Pt 8, Ch 1, 2 Riser systems*.

1.1.2 All structural steel work is to be suitably protected against loss of integrity due to the effects of corrosion. In general, suitable protective systems may include coatings, metallic claddings, cathodic protection, corrosion allowances or other approved methods. Combinations of methods may be used when agreed by Lloyd's Register (LR). Consideration should be paid to the design life and the maintainability of the surfaces in the design of the protected systems.

1.1.3 The basic Rule scantlings of the external submerged steel structure of units which are derived from *Pt 4 STEEL UNIT STRUCTURES* assume that a cathodic protection system will be effective and in use continually. Unless agreed otherwise with LR no corrosion allowance will be included in the approved scantlings, *see Pt 3, Ch 1, 5 Corrosion control*.

1.2 Zone definitions

1.2.1 The type of protection of the steelwork is to be suitable for the structural location of the unit and for this purpose the steel structure is to be considered in terms of zones.

1.2.2 **Submerged zone**. That part of the external structure below the maximum design operating draught.

1.2.3 **Boot topping zone**. That part of the external structure between the maximum design operating draught and the light design operating draught. For column-stabilised units, *see Pt 8, Ch 1, 1.2 Zone definitions 1.2.6*.

1.2.4 **Splash zone**. That part of the external structure above the boot topping zone subject to wet and dry conditions.

1.2.5 **Atmospheric zone**. That part of the external structure above the splash zone.

1.2.6 **Internal zones**. Ballast tanks, liquid storage tanks, and other compartments.

Table 1.1.1 Minimum corrosion protection requirements for external structural steelwork

Unit type	Corrosion protection required and area		
	Zone	Structural steelwork	Method of protection required
Column-stabilised units and tension-leg units	Submerged zone	Columns, lower hulls and bracings	Cathodic protection and coatings, *see* Notes 1 and 5
	Boot topping and splash zones, *see* Note 2	Columns, lower hulls and bracings	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only

Self-elevating units	Transit condition: Submerged, boot topping andsplash zones	Main hull	Coatings only
	Elevated condition: Submerged zone	Legs, footings and mats	Cathodic protection and coatings, *see* Note 5
	Boot topping and splash zones, *see* Note 4	Legs	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Ship units and other surfacetype units	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Deep draught caisson units and buoy units	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Mooring towers	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones, *see* Note 3	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
NOTES			
1. For the assignment of the In-Water Survey notation **OIWS**, corrosion protection by both cathodic protection and high resistance paint coatings is required.			
2. For column-stabilised units the boot topping zone is to be taken as that part of the external structure between the maximum design operating draught and the transit draught.			
3. For mooring towers the boot topping zone is to extend between the lowest and highest atmospheric tides at the operating location.			
4. For self-elevating units, in the elevated position, the boot topping zone is to extend between the lowest and highest atmospheric tides at the operation location.			
5. For mobile offshore units, if In-water Survey notation, **OIWS**, is not assigned, coatings may be omitted except in the boot topping zone, *see* Note 2.			

1.3 External zone protection

1.3.1 The minimum requirements for corrosion protection of the external steelwork of offshore units is given in *Pt 8, Ch 1, 1.2 Zone definitions 1.2.6*.

1.3.2 The structural steelwork in the boot topping and splash zones is normally to be protected by suitable coatings but consideration may be given to the following:

(a) Extra steel in excess of the Rule requirements.
(b) Metallic cladding resistant to the environment where appropriate.

1.3.3 The structural steelwork in the atmospheric zone is to be protected by suitable coatings.

1.3.4 The structural steelwork in the submerged zone is to be protected by an approved means of cathodic protection using sacrificial anodes or an impressed current system, except where noted otherwise in *Pt 8, Ch 1, 1.2 Zone definitions 1.2.6*. High resistance coatings may be required or used in conjunction with a cathodic protection system but they will not be accepted in lieu except where noted in *Pt 8, Ch 1, 1.2 Zone definitions 1.2.6*. An alternative means of protection such as increased scantlings may be considered in special areas. Where In-Water Survey notation OIWS is to be assigned corrosion, protection in submerged zone shall be provided by high resistance coatings supplemented by cathodic protection; this is considered to be the optimal means of protection for all submerged components.

1.4 Internal zones

1.4.1 Ballast tanks shall be protected from corrosion by a combination of anti-corrosion coatings and cathodic protection.

1.4.2 At the time of new construction, all salt-water ballast tanks shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations. The durability of the coatings could affect the frequency of survey of the tanks and light coloured coatings would assist in improving the effectiveness of subsequent surveys. It is therefore recommended that this be taken into account by those agreeing the specification for the coatings and their application.

1.4.3 Storage tanks and other compartments require corrosion protection where the storage product may be corrosive. Particular attention should be paid to the likelihood of water in the bottom of hydrocarbon storage tanks and the effects of bacterial induced corrosion. Suitable protective measures may include coatings, corrosion inhibitors together with biocides.

1.4.4 In deep draught caisson units and other units with combined oil storage and ballast tanks which remain full during the service life of the unit, special consideration will be given to the requirement for internal corrosion protection of the tanks. In general, the minimum Rule scantlings of tanks as required by*Pt 4, Ch 6, 7 Bulkheads* are to be suitably increased based on a study of likely degradation rates and service life of unit.

1.5 Bimetallic connections

1.5.1 Where bimetallic connections are made in the structure, suitable measures are to be incorporated to preclude galvanic corrosion. Details are to be submitted for approval on the structural plans required in *Pt 4, Ch 1, 4 Information required* The combination of painting the less noble material and leaving the more noble material uncoated for an immersed bimetallic couple is not permitted. In submerged zones cathodic protection is considered to be a suitable mitigation measure as it will eliminate the potential differences across the bimetallic connection.

1.6 Chain cables and wire ropes

1.6.1 Chain cables and wire ropes for positional mooring systems are to be protected from corrosion and the requirements of*Pt 3, Ch 10 Positional Mooring Systems* are to be complied with. Current drain from the mooring system is to be considered in cathodic protection design as required in *Pt 8, Ch 4, 1 External steel protection*.

■ *Section 2*
Riser systems

2.1 General

2.1.1 Riser systems are to be suitably protected against corrosion. It is recommended that this be achieved using a coating combined with a cathodic protection system. Account should be taken of possible temperature effects. Other equivalent methods of protection will be considered.

2.1.2 The splash and boot topping zones of risers are to be specially considered. A corrosion allowance will be required in addition to any coatings. The corrosion allowance should be defined based on corrosion rate and service life in the relevant location and a default 6mm applied unless demonstrated to be onerous based on environmental conditions, materials and service life, deviations shall be agreed with LR. Risers in J-tubes, etc. will require separate assessment of protection.

2.2 External coatings

2.2.1 Paint or protective coatings are generally to be chosen in conjunction with the system of cathodic protection.

2.2.2 The performance of the coating materials used should be proven by previous service or by extensive and documented laboratory testing.

2.3 Internal protection

2.3.1 The method of internal protection is to take into account the corrosivity, bacterial content, solids/abrasive content, flow characteristics and temperature and pressure.

2.3.2 Materials or systems (e.g. liners) are to be evaluated against the service nature of the product to be conveyed. Proprietary specifications and in-service history are to be submitted as required by LR.

2.3.3 Where internal protection is proposed by use of corrosion inhibitors, the properties, compatibility and effect on product conveyed are all to be documented and submitted.

2.4 Cathodic protection systems

2.4.1 Cathodic protection systems are to comply with the requirements of *Pt 8, Ch 2 Cathodic Protection Systems*.

2.4.2 Visual inspection surveys with measurements of potential are to be taken periodically and any deficiencies in terms of potential readings above the protection potential of -0,8V Ag/AgCl or detached anodes corrected by the addition of extra sacrificial anodes or adjustment of ICCP system controls.

2.4.3 For ICCP systems, measurements are to be taken to confirm that there is no over-protection. Over-protection is considered to be readings more negative than -1.2V Ag/AgCl.

2.4.4 Stray currents, current drain and including that from the mooring system and interference from ships, other vessels or installations in the vicinity are to be evaluated and appropriate measures taken.

■ *Section 3*
Plans and information

3.1 Scope

3.1.1 In order that an assessment may be made of protection systems full details as outlined in this Section are to be submitted.

3.2 Cathodic protection systems

3.2.1 The following plans and information are to be submitted:

(a) A surface area breakdown for all areas to be protected including secondary steelwork and details of appurtenances.
(b) The resistivity of the sea water and sediments.
(c) All current densities used for design purposes.
(d) The type and location of any reference electrodes and their methods of attachment.
(e) Full details of any coatings used and the areas to which they are to be applied.
(f) Details of any electrical bonding.
(g) Details of current drain.
(h) Stray current considerations.

3.3 Sacrificial anode systems

3.3.1 In addition to the information required by *Pt 8, Ch 1, 3.2 Cathodic protection systems* the following plans and information are to be submitted:

(a) The design life of the system in years.
(b) Anode material and minimum design capacity of anode material, in Ah/kg.
(c) The dimensions of anodes including details of the insert and its location.
(d) The nett and gross weight of the anodes, in kg.
(e) The means of attachment.

(f) Plans showing the location of the anodes.
(g) Calculation of anodic resistance, as installed and when consumed to their design and utilisation factor, in ohms.
(h) Closed circuit potential of the anode material, in volts.
(i) Details of any computer modelling.
(j) The anode design utilisation factor.

3.4 Impressed current systems

3.4.1 In addition to the information required by *Pt 8, Ch 1, 3.2 Cathodic protection systems*, the following plans and information are to be submitted:

(a) The anode composition and where applicable the thickness of the plated surface, consumption and life data.
(b) Anode resistance, limiting potential and current output.
(c) Details of construction and attachment of anodes and reference electrodes.
(d) Size, shape and composition of any dielectric shields.
(e) Diagram of the wiring system used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in circuits, and the capacity, type and make of the protected devices.
(f) Details of glands and size of steel conduits.
(g) Plans showing the locations of the anodes and reference electrodes.
(h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

3.5 Coating systems

3.5.1 The following plans and information are to be submitted:

(a) Evidence that any primers used will have no deleterious effect on subsequent welding or on subsequent coatings.
(b) Details of the painting specification with regard to:
    (i) The generic type of the coating and conformation of its suitability for the intended environment;
    (ii) The methods to be used to prepare the surface before the coating is applied and the standard to be achieved. Reference should be made to established International or National Standards;
    (iii) The method of application of the coating; and
    (iv) The number of coats to be applied and the total dry film thickness.
(c) Details of the areas to be coated.
(d) Inspection and Testing Plan.

3.5.2 In addition to the information required by *Pt 8, Ch 1, 3.5 Coating systems 3.5.1* the following may also be required:

(a) When a coating contains aluminium and is intended to be used on decks or in areas where flammable gases may accumulate, a statement from an independent laboratory confirming that appropriate tests have shown that the coating does not increase the incendive sparking hazard in the area to which it is to be applied.
(b) Where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire risk, a statement that the coating is not formulated on a nitrocellulose or other highly flammable base and has low flame spread characteristics (complying to at least BS476: Part 7: Classification 2 or any other equivalent National Specification).

3.6 Inhibitors and biocides

3.6.1 Where it is proposed to use inhibitors, biocides, or other chemicals for the protection of storage tanks, full details, including compatibility with each other and evidence of satisfactory service experience or suitable laboratory test results or any other data to substantiate the suitability for the intended purpose are to be submitted for consideration.

■ *Section 1* General requirements

1.1 Objective

1.1.1 The cathodic protection system for the external submerged zone is to be designed for a period commensurate with the service life of the structure or the dry-docking interval and it should be capable of polarising the steelwork to a sufficient level in order to minimise corrosion at any point in the service life.

1.1.2 This may be achieved using either sacrificial anodes or an impressed current system or a combination of both, *see Pt 8, Ch 2, 3.2 Protection after launching and during outfitting 3.2.1*.

1.2 Electrical continuity

1.2.1 All parts of the structure should be electrically continuous and, where considered necessary, appropriate bonding straps should be fitted across such items as propellers, thrusters, rudders and legs, etc. and the joints of articulated structures are to be efficiently completed to the Surveyor's satisfaction.

1.2.2 Where bonding straps are not fitted, a supplementary cathodic protection system should be considered.

1.2.3 Particular attention to earthing and bonding is required in hazardous areas where flammable gases or vapours may be present, *see Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

To avoid dangerous sparking between metallic parts of structures, potential equalisation is always required for installations in Zone 1 and may be necessary for installations in Zone 2 areas; this is achieved by connecting all exposed and extraneous conductive parts to the equipotential bonding system. Notwithstanding this, cathodic protection installations are not to be connected to the equipotential bonding system unless the cathodic protection system is specifically designed for this purpose. *See* IEC 61892-7 Section 5.6.3.

Cathodically protected metallic parts are live extraneous conductive parts. If located in hazardous areas, they are to be considered potentially dangerous (especially if equipped with the impressed current method) despite their low negative potential.

No cathodic protection is to be provided for metallic parts in Zone 0 unless it is specially designed for this application. *See* IEC 61892-7 Section 5.6.6.

1.2.4 Consideration should be given to the influence of any connecting structures, such as risers and pipelines, on the efficiency of the cathodic protection system. A floating structure may be permanently or temporarily connected to another neighbouring structure. In this situation, the requirements of BS EN 13173 are to be met, including the taking of measurements to ensure that there are no deleterious effects of electrical stray current on the protected structure.

1.3 Criteria for cathodic protection

1.3.1 Cathodic protection systems are to comply with BS EN 13173 – *Cathodic protection for steel offshore floating structures* or BS EN 12495 – *Cathodic protection for fixed steel offshore structures* unless local legislation requirements dictate otherwise; replacement standards shall be listed and submitted to LR for approval..

1.3.2 The cathodic protection system is to be capable of polarising the steelwork to potentials measured with respect to a silver/silver chloride/sea-water (A_g/A_gCI) reference electrode to within the following ranges:

(a) –0,80 to –1,10 volts for aerobic conditions.

(b) –0,9 to –1,10 volts for anaerobic conditions.

1.3.3 Potentials more negative than –1,10 volts Ag/AgCl must be avoided in order to minimise any damage due to hydrogen absorption and reduction in the fatigue life. For steel with a tensile strength in excess of 700 N/mm^2 the maximum negative potential should be limited to –0,95 volt. But where the steel is prone to hydrogen assisted cracking the potential should not be more negative than –0,83 volt (Ag/AgCl reference cell).

1.3.4 High strength fastening materials should be avoided because of the possible effects of hydrogen, and the hardness of such bolting materials should be limited to a maximum of 300 Vickers Diamond Pyramid Number.

1.3.5 The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

1.3.6 For guidance on the design of sacrificial anode systems, *see Pt 8, Ch 4, 2 Protection of tanks*.

■ *Section 2*
Sacrificial anodes

2.1 General

2.1.1 Sacrificial anodes intended for installation on units are to be manufactured in accordance with the requirements of this Section.

2.1.2 Plans showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to manufacture.

2.1.3 Approval for the manufacture of anodes is not required although the anodes should preferably be type approved in accordance with Lloyd's Register's (LR's) *List of Type Approval Equipment*.

2.1.4 The works should have a quality management system certified by a recognised third-party certification body. However, alternative arrangements may be accepted provided they ensure a consistent quality for the anodes.

2.2 Anode materials

2.2.1 The anode materials are to be approved alloys of zinc or aluminium. A closed-circuit potential more negative than –1,00 volt (Ag/AgCl reference electrode) for Zinc anodes and -1,05 volt (Ag/AgCl reference electrode) for Aluminium anodes shall be achieved in seawater at ambient temperature up to 30°C. Magnesium-based anodes may be used for short-term temporary protection of materials not susceptible to hydrogen embrittlement, *see also Pt 8, Ch 2, 2.13 Anode installation 2.13.12*. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

2.3 Steel insert preparation

2.3.1 The anode material is to be cast around a steel insert so designed as to retain the anode material even when it is consumed to its design utilisation factor.

2.3.2 The steel inserts are to have sufficient strength to withstand all external forces that they may normally encounter such as wave, wind, ice loading and operating conditions.

2.3.3 The anodes are to be sufficiently rigid to avoid vibration in the anode support.

2.3.4 The steel inserts are to be of weldable structural steel bar, section or pipe with a carbon equivalent not greater than 0,45 per cent determined using the following formula:

Carbon equivalent, $C_{\mathrm{eq}} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} = \mathrm{Cu}}{15}$

Rimming steel is not permitted.

2.3.5 Requirements for welded fabrication and non-destructive testing are to be in accordance with *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.3.6 The steel insert is to be degreased if necessary and blast cleaned to a standard equivalent to ISO 8501-1 Sa 21/2 with a minimum surface profile of 50 µm. This standard of cleanliness is to be maintained up until the time of castings. For zinc anodes, blast cleaning may be followed by galvanising or by an approved zinc plating process.

2.4 Chemical composition

2.4.1 The chemical composition of the heat is to be determined prior to casting. No alloying additions are to be made following chemical analysis without further analysis. For heats greater than 1 tonne, a further sample is to be analysed at the end of the cast. All anodes cast are to comply with the approved specification. Typical chemical compositions for Al-Zn-In type and zinc type anodes which are known to perform well in many conditions are provided below. Other compositions may be used if testing demonstrates that the required electrochemical properties can be achieved. Any testing shall be submitted to LR for approval.

Table 2.2.1 Aluminium anode composition

Element	Mass Fraction (w)	
	Min. %	Max. %
Zn	2,5	5,75
In	0,016	0,040
Fe	–	0,09
Si	–	0,12
Cu	–	0,003
Cd	–	0,002
Others	–	0,02 (each)
Al	Remainder	

Table 2.2.2 Zinc anode composition

Element	Mass Fraction (w)	
	Min. %	Max. %
Cu	2,5	0,005.
Al	0,016	0,50
Fe	–	0,005
Cd	–	0,07
Pb	–	0,006
Zn	Remainder	

2.5 Conditions of supply

2.5.1 Generally anodes are to be supplied in the as-cast condition although certain aluminium anodes may be heat treated in accordance with the approved specification.

2.5.2 Where heat treatment is carried out it is to be in properly constructed furnaces which are efficiently maintained and have adequate means for the control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature.

2.6 Anode identification

2.6.1 The manufacturer is to adopt a system of identification of the anodes to enable the material to be traced back to its original cast.

2.6.2 The anodes are to be clearly marked with the following:

(a) Name or initials of the anode manufacturer.
(b) Number and/or initials to identify the batch.
(c) Agreed identification mark for the anode material.

2.6.3 Where the anodes are heat treated they are also to be marked with the appropriate heat treatment batch number.

2.7 Anode inspection

2.7.1 All anodes are to be cleaned and adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. However, any flash or other protrusions should be removed prior to inspection.

2.7.2 Anodes are to be inspected prior to the application of any coating which may be applied to the underside of the anode or to the exposed steelwork.

2.7.3 The surface should be free of any significant slag or dross or anything that may be considered detrimental to the satisfactory performance of the anodes.

2.7.4 Shrinkage depressions should not exceed the smaller of 10 per cent of the nominal depth of the anode or 50 per cent of the depth to the anode insert.

2.7.5 Cracks in the longitudinal direction are not acceptable. Small transverse cracks may be permitted provided:

(a) They are not more than 5 mm in width;
(b) They are within the section wholly supported by the steel insert;
(c) They do not extend around more than two faces or 180° of the anode circumference; and
(d) The Surveyor is satisfied that there has been no breakdown in Quality Control procedures.

2.7.6 Cold shuts or surface laps should not exceed a depth of 10 mm or extend over a total length equivalent to more than three times the width of the anode. All material is to be completely bonded to the bulk material.

2.8 Dimensions

2.8.1 The accuracy and verification of dimensions is the responsibility of the manufacturer unless otherwise agreed.

2.8.2 The diameter of cylindrical anodes should be within ±5 per cent of the nominal diameter.

2.8.3 For long slender anodes the following dimensions should apply:

(a) Mean length ±3 per cent of nominal length or ±25 mm, whichever is smaller.
(b) Mean width ±5 per cent of nominal width.
(c) Mean depth ±10 per cent of nominal depth.

2.8.4 The maximum deviation from straightness should not exceed two per cent of the length.

2.8.5 The steel insert should be within ±5 per cent of the nominal position in anode width and length and within 10 per cent of the nominal position in depth. Some anodes may have the insert close to one surface, in which case a closer tolerance may be more appropriate.

2.8.6 Except where previously agreed, the anode insert fixing dimensions are to be within ±1 per cent of the nominal dimensions or 15 mm, whichever is the smaller.

2.8.7 Anode nominal dimensions, tolerances and fabrication details are to be shown on manufacturing plans prepared by the manufacturer and submitted for approval, *see Pt 8, Ch 1, 3.3 Sacrificial anode systems*.

2.9 Anode weight

2.9.1 Anodes are to be weighed and individual anodes should be within ±5 per cent of the nominal weight for anodes less than 50 kg or ±3 per cent of the nominal weight for anodes 50 kg and over.

2.9.2 No negative tolerance is permitted on the total contract weight and the positive tolerance should be limited to two per cent of the nominal contract weight.

2.10 Bonding and internal defects

2.10.1 It will be necessary for the manufacturer to demonstrate that there is a satisfactory bond between anode material and the steel insert and that there are no significant internal defects. This may be carried out by sectioning of an anode selected at random from the batch or by other approved means.

2.10.2 Where sectioning is carried out, at least one anode or at least 0,5 per cent of each production run is to be sectioned transversely at 25 per cent, 33 per cent and 50 per cent of the nominal length of the anode or at other agreed locations for a particular anode design.

2.10.3 The cut surfaces are to be essentially free from slag or dross.

2.10.4 Small isolated gas holes and porosity may be accepted provided their surface area is not greater than two per cent of the section.

2.10.5 No section is to show more than 10 per cent lack of bond between the insert and the anode material.

2.11 Electrochemical testing

2.11.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as-cast electrochemical properties.

2.12 Certification

2.12.1 The manufacturer is to provide copies of the Material Certificate or shipping statement for all acceptable anodes.

2.12.2 The certificate is to include at least the following information:

(a) Name of manufacturer.
(b) Description of anode, alloy designation or trade name.
(c) Cast identification number.
(d) Chemical composition.
(e) Details of heat treatment where applicable.
(f) Results of electrochemical test.
(g) Weight data.
(h) Purchaser's name and order number, and the name of the structure for which the material is intended.

2.12.3 The manufacturer is to confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and the Rules.

2.13 Anode installation

2.13.1 The location and means of attachment of anodes are to be submitted for approval.

2.13.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.13.3 Where bracelet anodes are proposed the tightness of the anodes is not to rely on the anode material being in direct contact with the structure.

2.13.4 The location and attachment of anodes are to take account of the stresses in the members concerned. Anodes are not to be directly attached to the shell plating of main hull columns or primary bracings.

2.13.5 The anode supports may be welded directly to the structure in low stress regions provided they are not attached in way of butts, seams, nodes or any stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.13.6 The attachment of all anodes to primary bracing members and nodes is to be submitted for approval. Anodes are not to be welded directly to the structure and the supports are to be welded to small doubler plates which are attached by continuous welds to the structure.

2.13.7 All welding is to be carried out by qualified welders using a qualified welding procedure in accordance with *Ch 12 Welding Qualifications*and *Ch 13 Requirements for Welded Construction*of the Rules for Materials.

2.13.8 The welds are to be examined using magnetic particle inspection or other acceptable means of non-destructive testing in accordance with *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

2.13.9 Anodes attached to studs 'fired' into the structure are not permitted.

2.13.10 The anodes are to be located on the structure to ensure rapid polarisation of highly stressed areas such as node welds and with due regard to a possible reduction in throwing power in re-entrant angles.

2.13.11 Anodes should not be located in positions where they may be damaged by craft coming alongside.

2.13.12 Magnesium anodes are not to be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted, *see Pt 8, Ch 2, 2.2 Anode materials 2.2.1*.

■ *Section 3*
Impressed current anode systems

3.1 General

3.1.1 Impressed current anode materials may be of leadsilver alloy or platinum over such substrates as titanium, niobium, tantalum, or of mixed oxides-activated titanium. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

3.1.2 The design and installation of electrical equipment and cables is to be in accordance with the requirements of *Pt 6, Ch 2 Electrical Engineering*.

If hazardous areas are present on the facility, the impressed current cathodic protection system and equipment is to comply with the requirements of*Pt 6, Ch 2 Electrical Engineering* (in particular *Pt 6, Ch 2, 5 Supply and distribution*), *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*, *Pt 7, Ch 2, 9 Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)*, *Pt 7, Ch 2, 10 Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk* and *Pt 7, Ch 2, 11 Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes*, IEC 60079 series and IEC 60092-502.

IEC 60092-502 Clause 5.7 'Cathodically protected metallic parts' states 'No impressed current cathodic protection shall be provided for metallic parts in hazardous areas, unless it is specially designed for this application and acceptable to the appropriate authority'.

The insulating elements required for the cathodic protection, for example, insulating elements in pipes and tracks, should if possible be located outside the hazardous area. *See* IEC 61892-7 Section 5.6.6.

3.1.3 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the storage of low flashpoint oils. Where cables are led through cofferdams of oil storage units they are to be enclosed in a substantial steel tube of about 10 mm thickness.

3.1.4 The arrangement for glands, where cables pass through shell boundaries, are to include a small cofferdam.

3.1.5 Cable and insulating material should be resistant to chloride, hydrocarbons and any other chemicals with which they may come into contact.

3.1.6 The electrical connection between the anode cable and the anode body is to be watertight and mechanically and electrically sound.

3.1.7 Where the power is derived from a rectified a.c. source, adequate protection is to be provided to trip the supply in the event of:

(a) A fault between the input or high voltage windings of the transformer (i.e. main voltage) and the d.c. output of the associated rectifier; or
(b) The ripple on the rectified d.c. exceeding 5 per cent. The requirements for transformers and semi-conductor equipment are given in *Pt 6, Ch 2, 9 Rotating machines*.

3.1.8 Anodes may be installed by mounting in insulating holders attached directly to the submerged structural member provided the general requirements given in *Pt 8, Ch 2, 2.13 Anode installation* regarding attachments to the structure are complied with.

3.1.9 Suitable dielectric shields are to be fitted in order to avoid high negative potentials.

3.1.10 A warning light or other warning indicator is to be arranged at the control position from which divers are controlled to indicate that the impressed current cathodic protection system has been switched off when divers are in the water.

3.2 Protection after launching and during outfitting

3.2.1 Where protection is primarily by an impressed current cathodic protection system, sufficient sacrificial anodes are to be fitted, capable of polarising the critical regions of the structure from the time of initial immersion until full commissioning of the impressed current system.

■ *Section 4*
Fixed potential monitoring systems

4.1 General

4.1.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system, and, although not essential, such a monitoring system is recommended for use in conjunction with sacrificial anodes. Monitoring schemes shall comply with BS EN 13509 – *Cathodic protection measurement techniques*.

4.1.2 Zinc or Ag/AgCl reference electrodes should be used. Reference electrode materials and design specified in the above standard are also permitted.

4.1.3 Variations between electrodes of ±30 mV have been reported for zinc/sea-water reference electrodes and ±5 mV for silver/silver chloride/sea-water electrodes but unless a high degree of stability is required, either electrode may be used for comparison purposes. The zinc/sea-water electrode may be taken as approximately 1,03 V more positive than the silver/silver chloride/sea-water electrode.

4.1.4 The location and attachment of the reference electrodes are to take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any stress raisers.

4.1.5 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

4.1.6 The reference electrodes may be connected to the top side display and control equipment by suitable cabling or by any other agreed means.

4.1.7 Provision is to be made for the regular recording at an agreed interval of the potential of the steelwork and log sheets are to be made available for inspection when required by LR Surveyors.

■ *Section 5*
Cathodic protection in tanks

5.1 General

5.1.1 Impressed current cathodic protection systems are not to be fitted in any tank.

5.2 Sacrificial anodes

5.2.1 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other inflammable vapour, both in relation to the structural arrangements and openings of the tanks.

5.2.2 Aluminium and aluminium alloy anodes are permitted in tanks that may contain explosive or flammable vapour, or in ballast tanks adjacent to tanks that may contain explosive or flammable vapour, but only at locations where the potential energy of the anode does not exceed 275 J (28 kgf/m). The weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. The height is to be taken as the distance from the bottom of the tank to the centre of the anode but exception to this may be given where the anodes are located on wide horizontal surfaces from which they cannot fall.

5.2.3 Aluminium anodes are not to be located under tank hatches or other openings unless protected by adjacent structure.

5.2.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast, in which case adequate venting must be provided.

5.2.5 Anodes fitted internally should preferably be attached to stiffeners, or aligned in way of stiffeners on plane bulkhead plating. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding at least 25 mm away from the edge of the web.

5.2.6 In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the mild steel face-plate but well clear of the free edges. Where higher tensile steel face-plates are fitted the anodes are to be attached to the webs.

5.2.7 Anodes are not to be attached directly to the shell plating of main hulls, columns or primary bracings.

5.2.8 For guidance on the design of sacrificial anode systems in tanks, *see Pt 8, Ch 4, 2 Protection of tanks*.

■ *Section 6* Potential surveys

6.1 General

6.1.1 Potential surveys of the external submerged zones are to be carried out at agreed intervals, *see also Pt 1, Ch 3 Periodical Survey Regulations*.

6.1.2 Should the results of any potential survey measured with respect to a Ag/AgCl reference cell indicate values more positive than –0,8 volt for aerobic conditions or –0,9 volt for anaerobic conditions then remedial action such as retrofit of sacrificial anode or adjustment and maintenance of ICCP system is to be carried out at the earliest opportunity.

■ *Section 7* Retrofits

7.1 General

7.1.1 Where it is proposed to fit additional anodes or replace existing ones, full details including information listed below are to be submitted for consideration.

(a) Existing CP system performance study
(b) Cause of any premature failure of the system
(c) Design calculations and drawings
(d) CP potential modelling
(e) Deviations from class requirements based on in service performance on station

7.1.2 Where it is necessary to weld anodes to the structure, only approved welding procedures and consumables are to be used, in accordance with *Ch 12 Welding Qualifications*and *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

■ *Section 1* General requirements

1.1 General

1.1.1 The painting specification is to be submitted for approval, *see Pt 8, Ch 1, 3.5 Coating systems 3.5.1*.

1.1.2 Paints, varnishes and similar preparations having nitrocellulose or any other highly flammable base are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire-risk.

1.1.3 Where a coating is to be applied in accommodation spaces and areas of similar fire-risk, the coating is to have low flame spread characteristics, *see Pt 8, Ch 1, 3.5 Coating systems 3.5.2*

1.1.4 Paints or other similar coatings containing >10% aluminium by weight in dry film should not be used in positions where flammable vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

1.1.5 Any sheathing or composition to protect decks is to be applied in such a manner that corrosion will not occur unseen beneath the covering.

1.1.6 Deck coatings or coverings used on decks forming the crown of spaces with a high fire-risk (such as helidecks, machinery and accommodation spaces) or which are within accommodation spaces, control rooms, emergency escape routes, etc. are to be of a type which will not readily ignite, *see Pt 8, Ch 1, 3.5 Coating systems 3.5.2*

1.1.7 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used.

1.1.8 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of ISO 8501-1 Sa 2½. All resulting dust is to be removed from the surface prior to the application of any paint.

1.1.9 The selection, application and maintenance of coatings for dedicated sea-water ballast tanks (including pre-load tanks on self-elevating units), double-side skin spaces, etc. are also to comply with *Resolution MSC.215(82) - Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers - (Adopted on 8 December 2006) Performance Standards for Protective Coatings*. All dedicated sea-water ballast tanks and double-side skin spaces are to comply with all of the requirements of the Resolution.

1.1.10 Maintenance of the protective coating systems is to be included in the unit's overall maintenance scheme.

1.1.11 The paint (and/or primer) used on the inner hull of some LNG containment systems (particularly membrane type) requires the use of a suitable paint system to provide adhesion of the containment system (via a curing mastic) to the inner hull, in accordance with the designer's specification, as approved by LR.

■ *Section 2* Prefabrication primers

2.1 General

2.1.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

2.1.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in *Pt 8, Ch 3, 2.1 General 2.1.3* to *Pt 8, Ch 3, 2.1 General 2.1.5*. *See* Lloyd's Register's (LR's) *List of Paint Resins, Reinforcements and Associated Materials*.

2.1.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A vee preparation is to be used and prior to welding, the surfaces and edges are to be treated as follows:

(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

2.1.4 Tests as follows are to be taken from each test assembly:

(a) **Radiographs**. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) **Photo-macrographs**. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) **Face and reverse bend test**. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.
(d) **Impact tests**. Tests are to be carried out, at ambient temperature, on three Charpy V-notch test specimens prepared in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*. The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

2.1.5 The tests are to be carried out in the presence of an LR Surveyor or by an independent laboratory specialising in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

Section

■ Section 1 External steel protection

1.1 Current density

1.1.1 The current density required for the external protection of the submerged zone of units will depend on many factors such as water temperature, oxygen content, resistivity of the water, suspended solids, water currents and biological activity.

1.1.2 Design current density values are given in *Pt 8, Ch 4, 1.1 Current density 1.1.2* for guidance purposes, but the values to be used should be based on the environmental conditions prevailing at the site. It should be noted that these values may be appreciably different from values actually measured on steelwork in the vicinity of the site.

Table 4.1.1 Current density values for design purposes

Location	Current density mA/m2		
	Initial	Mean	Final
Cook inlet	400	400	400
North Sea (Northern) Above 62°N	220	100	130
55°N to 62°N	180	90	120
North Sea (Southern) Below 55°N	150	80	100
Arabian Gulf, Africa, Brazil, China, India	130	70	90
Mediterranean, Australia (Western), Gulf of Mexico, Adriatic Sea, US West Coast	110	60	80
Mud – Most locations	25	20	20
Drainage per well	5A		

NOTES

1. The current density values are intended for guidance purposes in the design of sacrificial anode systems using the methods as outlined in this Chapter. However, other values may be accepted provided that there is adequate justification.

2. For impressed current cathodic protection systems, current densities higher than the values given in the Table may be necessary but this will depend on the type, location and quantity of the anodes.

1.1.3 In order to minimise pitting, the cathodic protection system must be capable of rapidly polarising the steelwork and the cathodic protection design must demonstrate that the system is capable of initially polarising the structure rapidly In order to minimise pitting.

1.1.4 The cathodic protection system must be capable of re-polarising the steelwork rapidly after storms, even when the anodes are well wasted, this should be demonstrated in design calculations.

1.1.5 Where suitable high resistance coatings are used, consideration will be given to use of current densities lower than those given in *Pt 8, Ch 4, 1.1 Current density 1.1.2*.

1.1.6 Coatings will deteriorate with time and there is likely to be mechanical damage. In order to take this into account at the design stage, appropriate coating breakdown factors should be applied and these are to be based on the percentages given in *Pt 8, Ch 4, 1.1 Current density 1.1.7*.

1.1.7 For an epoxy or coal tar epoxy coating applied to give a dry film thickness of 250 to 500 microns, an initial coating breakdown factor of one to two per cent for the submerged zone and an annual degradation rate of one to one and a half per cent per year should be used, in line with ISO 13173, unless agreed otherwise with Class. Coating breakdown factors for high build coatings, applied to give a dry film thickness of 1000 to 3000 microns should be lower and agreed with Class.

1.1.8 For other coating systems an initial breakdown factor of minimum 5% should be used and added to any area that is visibly damaged. Due allowance should be made for further breakdown during the service life given in *Pt 8, Ch 4, 1.1 Current density 1.1.7*.

1.1.9 Current drain due to risers, mooring lines and other electrically connected structures shall be considered in the current requirement calculations and be fully documented.

1.1.10 Current density of propeller and rudder components and surrounding areas are likely to require a significantly higher current density to polarise and maintain protection through life. Design of cathodic protection systems for propeller and rudder components should be based on a minimum current density of 400mA/m^2 and 200mA/m^2 respectively.

1.2 Sacrificial anode systems

1.2.1 The following indicates an acceptable method for determining the number and weight of anodes to achieve the required level of polarisation on most structures. Other methods may be accepted provided they give reasonable equivalence.

1.2.2 The type of anode selected must be of sufficient mass with appropriate dimensions to ensure an adequate current output throughout its design life.

1.2.3 The current output of the anode should be calculated using the following formula:

$$I_{\mathrm{a}} = \frac{[\mathrm{vtri}]\mathrm{V}}{R_{\mathrm{a}}}$$

where

I_{a} = current output of anode, in amps

ΔV = driving potential, i.e. the difference between the potential of the mode and the protected steel potential, in volts

R_{a} = anodic resistance, in ohms.

1.2.4 The potential of the polarised steel should be taken as –0,8 volt ($\mathrm{A_g/A_gCI}$ /sea-water reference electrode), although a more negative value may be used for those locations where sulphate-reducing bacteria may be active, *see Pt 8, Ch 2, 1.3 Criteria for cathodic protection*.

1.2.5 The resistance of an anode, *R*, with small cross-section in relation to its length (4r≤L) and with a stand-off distance from the bottom of the anode surface to the structure of not less than 300 mm, is given by:

(a) $$R = \frac{\mathrm{r}}{2\,\pi\,l_{\mathrm{a}}}\left(ln\frac{4l_{\mathrm{a}}}{\rho} - 1\right)$$

where

$\boldsymbol{\rho}$ = resistivity of sea-water, in ohm.cm

l_{a} = length of anode, in cm

r = equivalent radius of anode, in cm

ln = $\log_e$

r = $\sqrt{\frac{a}{k}}$

a = cross-sectional area of the anode, in cm^2

(b) When bracelet anodes are used, the resistance may be determined using:

$$R = \frac{0,315\,\rho}{\sqrt{A_e}}$$

where

A_e = the exposed surface area of the anode, in cm^2.

1.2.6 In order to achieve a suitable anode distribution on tubular structures, each appropriate section of steelwork should be considered separately.

1.2.7 The current required for each section may be determined from the following:

$$I_r = \frac{AI}{1000}$$

where

I_r = current, in amps

A = area of steelwork, in m^2

I = current density, in mA/m^2.

1.2.8 The number of anodes, N, required should satisfy both of the following:

$$N = \frac{I_r}{I_a}$$

$$N = \frac{W_r}{W_a}$$

where

I_r = current, in amps

I_a = current output of anode, in amps

W_r = net weight of anode material, in kg

W_a = net weight of individual anode, in kg

W_r = $\frac{I_r Y 8760}{CU}$

Y = life of structure or appropriate dry-docking interval in years, *see Pt 8, Ch 2, 1.1 Objective 1.1.1*

C = practical electrochemical capacity of the alloy, in Ah/kg

U = utilisation factor, i.e. proportion of net weight consumed at end of anode life. For fully supported tubular inserts

$U = 0,9$

U = 0,8 for bracelet (half shell)
U = 0,75 for bracelet (segmental type).

In order to optimise the performance and efficiency of the anodes the values for both equations should be similar.

1.2.9 It is to be shown by appropriate calculations that the system is capable of polarising the structure initially and also when the anodes are consumed to their design utilisation factor.

1.2.10 It should be assumed that, at the end of its life, the anode length has been reduced by 10 per cent and that the remaining material is evenly distributed over the steel insert.

1.3 Location of anodes

1.3.1 Having determined the number and size of the anodes to comply with the recommended nominal current density and the required life, the anodes should be distributed over the steel surfaces according to the required level of protection on the steelwork but with some emphasis on the area adjacent to joints, etc. CP potential modelling can be considered to aid distribution to ensure full coverage. The anodes associated with the structure likely to become buried, such as footings, etc. should be positioned on the steelwork immediately above the mudline.

■ *Section 2* Protection of tanks

2.1 Anode resistance

2.1.1 Where large stand-off anodes are used for the protection of tanks, the resistance should be determined using the formula as given in *Pt 8, Ch 4, 1.2 Sacrificial anode systems 1.2.5*

2.1.2 Where flat plate anodes are used, their resistance is to be determined from the following formula:

$$R = \frac{\rho}{4l_{\mathrm{m}}}$$

however, if the flat plate anodes are close to the structure or painted on the lower face then the resistance is to be determined using:

$$R = \frac{\rho}{2l_{\mathrm{m}}}$$

where ρ is as defined in *Pt 8, Ch 4, 1.2 Sacrificial anode systems 1.2.5*

l_{m} = mean length of anode sides, in cm.

2.2 Current density

2.2.1 The design current density to be used for permanent water ballast tanks should be based on a minimum value of 110 mA/m^2 but this may have to be increased to at least 130 mA/m^2 if hot oil is stored on the opposite side of the bulkhead. For a coating allowance, *see Pt 8, Ch 4, 1.1 Current density 1.1.6*.

2.2.2 Uncoated tanks used for the storage of crude oil at ambient temperature alternating with water ballast are to have a minimum current density of 90 mA/m^2; however, this should be increased for higher temperatures.

2.2.3 Unless otherwise agreed the resistivity of the water in ballast tanks should be assumed to be 25 ohm.cm.

2.3 Anode distribution

2.3.1 Once the number and size of anodes have been determined, they are to be distributed as follows:

(a) **Ballast-only tanks**: evenly over all the steelwork with some consideration given to the lower sections based on usage pattern and ballasting levels.
(b) **Crude oil/ballast tanks**: evenly but with some emphasis on horizontal surfaces in proportion to the area of these surfaces.

Section 3
Surface preparation, application and maintenance of coatings

3.1 Application

3.1.1 These notes have been prepared to give general guidance on those aspects of surface preparation and application and the subsequent maintenance of coatings that should be taken into account by those agreeing the coating specification.

3.1.2 These notes are not intended to be used for contractual purposes or as representing the minimum requirements as these are a matter for the interested parties to agree.

3.1.3 The guidelines do not intend to replace the technical aspects of any specific coating system, to be covered by the product and job specifications, which are at the discretion and under the responsibility of Owners, manufacturers and construction yards.

3.1.4 Owners should select and maintain a corrosion protection system to ensure an adequate level of protection.

3.1.5 Coating manufacturers should give evidence of the quality of the product and its ability to satisfy the Owner's requirements.

3.1.6 Coating manufacturers should have products with documented service performance records. Coatings recognised by Lloyd's Register (LR) are considered as satisfying this requirement, *see* list of LR approved PSPC compliant coatings on Class Direct. Where it is proposed to use coatings without satisfactory performance records, coating selection should be supported by appropriate laboratory test data carried out in accordance with recognised Standards (e.g. ISO 20340) in order to verify their suitability for the intended service condition.

3.1.7 The construction yard and/or its subcontractors should provide clear evidence of their experience in coating application. The coating standard, job specification, inspection, maintenance and repair criteria should be agreed by the construction yard and/or its subcontractors, Owner and manufacturer.

3.2 General requirements

3.2.1 At present, hard coatings are the most commonly used for new construction.

3.2.2 As their effectiveness and life are influenced by several factors it is essential that the manufacturer's technical product data sheet and job specifications are followed.

3.2.3 Multi coat applications with coating layers of contrasting colours are recommended. The last coating layer in ballast tanks should be of a light colour in order to facilitate in-service inspections.

3.2.4 Measures should be adopted at the design stage to reduce scallops, use rolled profiles (provided this does not adversely affect fatigue performance) or three-pass grinding where possible and ensure that the structural configuration permits easy access for personnel and equipment and facilitates cleaning, draining and drying of tanks.

3.2.5 Where a coating is supplemented by cathodic protection, the coating must be compatible with the cathodic protection system.

3.3 Coating selection

3.3.1 In the selection of a coating for use in ballast tanks, the following should be taken into account:

- Service conditions and planned maintenance.
- Frequency of ballasting/deballasting operations.
- Location of tank relative to heated surfaces.
- Required surface condition.
- Required surface cleanliness and dryness.
- Whether cathodic protection is to be fitted.
- Requirements of IMO Resolution *Resolution MSC.215(82) - Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers - (Adopted on 8 December 2006) Performance Standards for Protective Coatings*.

3.3.2 Coatings intended for use underneath solar heated decks or on bulkheads forming boundaries of heated cargo or fuel oil spaces should be able to withstand constant or repeated heating without becoming brittle or subject to a loss of adhesion. Due regard should be given to the possible poor edge-covering properties of hard coatings with a high solid content.

3.4 Initial preparation

3.4.1 Tubular scaffolding should not mask surfaces to be coated. Where contact is necessary, spade ends should be used.

3.4.2 Staging should afford easy and safe access to all surfaces to be coated.

3.4.3 Tubular scaffolding should be plugged or capped prior to blast cleaning to prevent the ingress of grit and dirt.

3.4.4 Staging should be designed to allow thorough cleaning.

3.4.5 Staging layout should be such that ventilation is not rendered ineffective.

3.4.6 Care should be taken when removing scaffolding in order to keep damages to a minimum. Any damages should be repaired in accordance with the paint manufacturer's recommendations.

3.4.7 External surfaces of pipelines which will be covered by pipe clips should be blasted and coated prior to fitting.

3.4.8 Pipeline exteriors should be blasted and coated at the same time as the lowermost parts of the tank. Any overblast or over-spray affecting surrounding areas should be repaired.

3.4.9 Lighting during blasting and painting must be electrically safe and provide suitable illumination for all work.

3.4.10 Powerful spotlighting must be provided for inspection work.

3.4.11 Adequate ventilation during application and drying of all paints is essential.

3.4.12 Flexible ventilation trunking should be used to allow the point of extraction to be reasonably close to the applicator.

3.4.13 The ventilation system and trunking should be so arranged that 'dead spaces' do not exist. Ventilation must be maintained during application and continued whilst solvent is released from the paint film during drying.

3.4.14 The ventilation system must prevent the vapour concentration exceeding 10 per cent of the lower explosive limit (or less than this if required by Regulations).

3.4.15 For coatings containing organic solvents, during the drying period an adequate number of air changes must be effected, depending on the type of coating being used. This ventilation should be maintained for at least 48 hours after the application of the system.

3.5 Surface preparation

3.5.1 Good surface preparation is one of the most important factors governing the performance of a coating. If contaminants such as oil, grease, dirt and chemicals are not removed from the surface they will prevent the adhesion of the coatings. Soluble salts on the surface may lead to osmotic blistering in the coating. Rust left on the surface will loosen, resulting in a loss of adhesion and if mill scale is not completely removed it will cause accelerated corrosion.

3.5.2 Good surface preparation roughens the surface and enables a good mechanical bond to be achieved.

3.5.3 All oil and grease is to be removed from the surface with suitable solvents prior to blast cleaning.

3.5.4 All welded areas and attachments are to be given special attention for the removal of welding flux and weld spatter. Sharp edges should be smoothed and any surface irregularities, including rough weld caps and slag together with rough edges, fins and burrs, should be mechanically treated using power wire brushing, grinding or chipping as appropriate.

3.5.5 Only dry abrasive blast cleaning techniques are to be employed and the conditions under which blast cleaning is carried out should preclude condensation. In this respect blasting should not normally be carried out under any of the following conditions:

(a) The surface temperature of the steel is less than 3°C above the dew point.
(b) The relative humidity is above 85 per cent.
(c) When there is any possibility that the surface of the steel is wetted before the first coat is applied.

3.5.6 The compressed air supply used for blasting is to be free of water and oil and adequate separators and traps are to be provided. Prior to using compressed air, the quality of the air downstream of the separator should be tested by blowing the air on to a clean white blotter or cloth for two minutes to check for any contamination, oil or moisture. This test should be performed at the beginning and end of each shift and at not less than four-hour intervals. If two consecutive tests show no contamination the

interval can be extended to once per shift, if subsequent tests show contamination then the four-hour interval is to be reinstated. The test also should be made after any interruption of the air compressor operation. The air should be used only if the test indicates no visible contamination, oil or moisture. If contaminants are evident, the equipment deficiencies should be corrected and the air stream should be retested.

3.5.7 Accumulations of oil and moisture are to be removed by regular purging of the system. Air compressors should not be allowed to work at temperatures in excess of 115°C.

3.5.8 The abrasive used for blasting should be dry and free from dirt, oil or grease and suitable for producing the standard of cleanliness and profile specified. Additionally, any organic or water soluble matter should be a maximum of 0,05 per cent by weight.

3.5.9 Iron or steel abrasives are not normally recommended for *in-situ* open blasting. If used, careful and thorough cleaning must be carried out to remove all traces of abrasive from the surface.

3.5.10 Although not recommended, recycled grit may be used providing it is correctly graded, dry and free from dirt, oil, grease, organic or water soluble matter. Recirculated grit should be checked for the presence of oil by immersing a sample in water and examining for oil flotation. Tests should be made at the start of blasting, and every four hours until the end of blasting. If compressor operations are interrupted for longer than five minutes, the air supply should be retested prior to use. If oil is evident, the contaminated abrasive should be cleaned or replaced. All surfaces blasted since the last successful test should be completely reblasted.

3.5.11 The amplitude of blast profile from trough to adjacent peak depends upon the type of coating to be applied. The amplitude should be not more than 50 μm for coatings of the zinc silicate type and not more than 75 μm of the high build coatings , unless otherwise specified by the manufacturer. A procedure to measure the surface profile of abrasive blast cleaned steel on site is given in NACE RP 0287.87. The technique utilises a tape that replicates the surface profile and the thickness of the tape is then measured using a micrometer.

3.5.12 Generally, where the final dry film coating is 125 μm or less, it should be in accordance with ISO 8501-1 Sa3 or an equivalent standard, i.e. the surface is to be cleaned to white metal such that a uniformly metallic, slightly roughened surface is produced completely free from foreign matter. Shadowed areas may only be accepted if they are due to differences in the structure of the steel or to a blast cleaning pattern. It should be noted that the possibility of achieving a uniform standard of Sa3 throughout the tanks is remote and a more realistic achievement would be somewhere between Sa2½ and Sa3.

3.5.13 The standard of surface preparation for the majority of the coatings is to be at least in accordance with ISO 8501-1 Sa2½ or an equivalent standard, i.e. the blast cleaned surface is to consist of at least 95 per cent cleaned bare steel and not more than 10 per cent of any single 25 mm square of the surface area is to be discoloured by areas of rust stain or mill scale residues.

3.5.14 In cases where the substrate is corroded or pitted it may be necessary to fresh water wash the areas after abrasive blasting, then reblast, in order to ensure complete removal of soluble corrosion products.

3.5.15 No acid washes or cleaning solutions are to be used on metal surfaces after they have been blasted. This includes inhibitive washes intended to prevent rusting.

3.5.16 Any substandard areas should be identified and must be brought up to the specified standard. Grease free chalk should be used to identify substandard areas and it should be removed after the substandard areas have been rectified.

3.5.17 After blast cleaning, all surfaces are to be freed of abrasive and dust by:

(a) Blowing with dry compressed air; or
(b) Vacuum cleaning.

To confirm that the blasted surfaces are sufficiently dust-free to allow successful coating, they are to be tested in accordance with ISO 8502-3 or an equivalent standard, to an extent and with acceptance criteria defined by the coating manufacturer.

3.5.18 Where surfaces have been coated with a prefabrication primer they are to be similarly cleaned before application of the coatings. If there is extensive breakdown of the primer, the surface affected is to be reblasted.

3.5.19 Since fresh blast cleaned surfaces are subject to immediate corrosion, particularly in areas of high humidity or in a marine atmosphere, it is essential that all cleaned surfaces are coated within four hours of cleaning. In any case, the surfaces are to be coated prior to the end of the working day and before any visible rusting occurs unless humidity can be maintained overnight at a low level.

3.5.20 Checks on the steel surface cleanliness and roughness profile should be carried out at the end of the surface preparation and before the application of the primer and in accordance with the manufacturer's specifications.

3.5.21 Where abrasive blast cleaning is demonstrated to be impracticable at specific locations, alternative mechanical surface cleaning techniques may be applied. In such circumstances, the surface cleanliness should be in accordance with ISO 8501-1 St3 or an equivalent standard and particular attention must be given to ensuring that the surface profile and soluble salt concentrations are in accordance with the coating manufacturer's specification.

3.6 Coating requirements

3.6.1 The composition of any primer used to coat steel after surface preparation and prior to fabrication must be such that it will have no significant deleterious effect on subsequent welding work.

3.6.2 The coatings are to be compatible with any prefabrication primer used and suitable for the intended application.

3.6.3 Materials are to be delivered in original containers with labels intact and the seals unbroken. Containers are to be kept in a safe, clean, well ventilated storage space.

3.6.4 Before use, coatings are to remain unopened in the original containers. Covers are to be kept on opened coating containers when not in use. Coatings are to be used in strict date order and not stored longer than six months unless permitted by the paint manufacturer.

3.6.5 The coating manufacturer's instructions are to be followed for storage, mixing, thinning and application of coatings along with the recommended time limit between coats and health and safety precautions. Only the thinners recommended by the manufacturer are to be used to thin coatings.

3.6.6 Coatings are to be mixed immediately prior to application. All coating materials are to be thoroughly mixed to give a homogeneous liquid without pigment settling out during application. Mechanical mixers are to be used for all coating mixing operations. The entire contents of the coating container are to be used in mixing to ensure the correct proportion of the base coat and pigment.

3.6.7 Coating material which has livered, discoloured, gelled, or otherwise deteriorated during storage is not to be used. Thixotropic materials which may be stirred to obtain normal consistency may be acceptable.

3.6.8 For coating materials requiring the addition of a catalyst, the pot life under application conditions is to be clearly stated on the label, and this pot life is not to be exceeded. When the pot life limit is reached, the spray pot is to be emptied, material discarded, and new material mixed.

3.6.9 Specification and data sheets on the coating materials are to be available at all times.

3.7 Coating application

3.7.1 The application of a coating should be a well planned activity, integrated in the yard's construction plans and carried out under controlled conditions to avoid conflicts with other yard operations.

3.7.2 Coatings should be applied in controlled humidity and surface temperature conditions to surfaces which have been blast cleaned to the coating manufacturer's recommended standard and immediately coated with a compatible prefabrication primer or applied after blast cleaning if this is permitted by the specification.

3.7.3 Areas where the prefabrication primer is damaged in any way may be touched up in accordance with the manufacturer's specifications.

3.7.4 Each coating layer should have the maximum/minimum thicknesses in accordance with the coating specification. Generally, an 80/20 practice may be adopted which means that 80 per cent of all thickness measurements should be greater than or equal to the nominal dry film thickness (DFT), and none of the remaining 20 per cent is below 80 per cent of the DFT. In the case of tanks (and especially ballast tanks), consideration should be given to adopting a 90/10 practice which means that 90 per cent of all thickness measurements should be greater than or equal to the nominal DFT, and none of the remaining 10 per cent is below 90 per cent of the DFT.

3.7.5 All paints should be applied by airless spray except for stripe coats where brushes or, if recommended by the coating manufacturer as a preferred option, rollers may be used.

3.7.6 Conventional spray may be used for the spraying of zinc silicate tank coatings.

3.7.7 Efficient mechanical stirrers for the correct mixing of paint should be used.

3.7.8 The spray equipment should comply with the paint manufacturer's recommendations. Adequate moisture traps should be fitted where appropriate so that water or oil can be continuously bled off from the air supply.

3.7.9 Lines and pots are to be thoroughly cleaned before using different materials.

3.7.10 With the possible exception of wet blast primers and moisture cured products, coatings should not be applied to damp surfaces and the specification should stipulate that coatings are not to be applied to surfaces where the relative humidity of the atmosphere is such that:

(a) Condensation is present on the surface; or
(b) It will affect the application of drying of the coating.

3.7.11 No coating is to be applied if the temperature is below that specified by the coating manufacturer and, in general, the metal surface temperature should be at least 3°C above the dew point before painting is commenced. The temperature, dew point, and relative humidity should be determined with a sling psychrometer. Suitable procedures are given in ASTM E337. Readings are required at the start of work and every four hours.

3.8 Coating thickness

3.8.1 Generally, high duty coatings should be applied in at least two coats; however, 'wet-on-wet' application may be considered as a two coat system provided:

(a) There is a time interval between the coats; and
(b) There is adequate attention to difficult areas such as welds, edges and any other changes in section and that the recommended coating thickness is achieved over all the structure.

3.8.2 Where coatings other than the zinc silicate type have been accepted as a single coat application, all welds, edges and any other changes in section may require a stripe coat to be applied.

3.8.3 Successive coats should preferably be of different colours or with a significant shade variation to give contrast and ensure complete coverage of the surface, *see also Pt 8, Ch 4, 3.2 General requirements 3.2.3*.

3.8.4 All surfaces are to receive the full thickness specified as a minimum. Areas with inadequate coating thickness should receive additional compatible coats until the specified coating thickness is attained. Coatings are to be brushed on to all areas which cannot be properly coated by spray.

3.8.5 Care should be taken to avoid an excessive coating thickness as this could lead to serious consequences, such as solvent and thinner retention, film cracks, gas pockets, etc. Wet coating thickness should be checked during application.

3.8.6 Each coating layer should be adequately cured before application of the next coat, in accordance with coating manufacturer's recommendations. Intermediate coats must not be contaminated with dirt, grease, dust, salt, over-spray, etc. Job specifications should include the dry-to-re-coat times given by the manufacturer.

3.8.7 Thinners should be limited to those types and quantities recommended by the manufacturer.

3.9 Inspection and repair

3.9.1 Wet film thickness checks should be made as the work progresses using appropriate thickness gauges.

3.9.2 Dry film thickness determinations should be carried out on all significant areas using suitable gauges. (The simple pull-off type gauges are not considered sufficiently accurate for this work.)

3.9.3 The full number of coats specified should be applied and the specified film thickness achieved.

3.9.4 All coatings should be free of pin holes, voids, bubbles and other 'holidays'. Holiday testing should be carried out using a suitable 'holiday detector' set at an appropriate voltage for the coating system.

3.9.5 Any defective areas are to be marked up and appropriate repairs effected. All such repairs are to be rechecked for any uncoated areas.

3.9.6 A daily log of the following is to be prepared:

(a) Air and steel temperatures.
(b) Relative humidity.
(c) Paint thicknesses measured.
(d) Extent of coating.
(e) Any other relevant information.

3.9.7 Damage to coatings is to be repaired by cleaning back to a sound base, recoating the affected areas as required in the specification and feathering to tie with adjoining areas. Prior to the application of any coating, all damage to previous coats is to have been repaired.

3.9.8 The area to be cleaned is to be carried over onto the firm surrounding coating for not less than 25 mm all round the edges. These are to be feathered by a suitable method to ensure continuity of the subsequent repair coating.

3.9.9 Areas with inadequate coating thickness are to be thoroughly cleaned and, if necessary, abraded and, where applicable, additional coats applied until the specification is complied with. These additional coats are to blend in with the final coating at adjoining areas.

3.9.10 Where welding has to take place on coated areas, unless they are approved prefabrication primers the coatings are to be removed locally and the surface after welding is to be prepared and recoated in accordance with the recommended procedures.

3.9.11 When dry film thicknesses are less than those specified, additional coats are to be applied as necessary to achieve specified thickness. For inorganic zinc silicate, areas of low film thickness should not be repaired by additional coats. In this case the coating is to be removed and the area re-coated to the specified thickness or paint manufacturer's recommendation.

3.10 Safety aspects

3.10.1 It should be noted that paints, coatings and thinners are potentially hazardous from health and safety points of view if not strictly controlled in accordance with good practice. Detailed advice on the safe working practices to be followed should be obtained from the relevant governmental safety agencies.

3.11 Maintenance

3.11.1 Maintenance of the corrosion protection system should be included in the overall maintenance schemes.

3.11.2 The most efficient way to preserve the corrosion protection system is to repair any defects found during the in-service inspections (e.g. spot rusting, local breakdown at edges of stiffeners, etc.).

3.11.3 During maintenance hard coatings should be restored using the type originally applied or by a compatible hard coating recognised by LR. The compatibility of coatings should normally be agreed by the paint manufacturer, and the coatings should be applied in accordance with the manufacturer's requirements.

3.11.4 The restoration of the damaged hard coatings by compatible coatings not recognised by LR will be accepted, provided such coatings are applied and maintained in accordance with the manufacturer's specification. Details of such coatings are to be reported for information and record purposes.

3.11.5 If the required conditions for the application of the original coating are not achievable, a coating more tolerant of a lower quality of surface treatment, humidity and temperature conditions may be considered, provided that it is applied and maintained in accordance with the manufacturer's specifications.

3.11.6 Currently there are numerous non-oxidising soft coatings which are being marketed for the purpose of repairing hard coatings. Proposals to use this type of coating, including the manufacturer's confirmation of their compatibility with the existing coatings, are to be referred for consideration.

3.11.7 It should be noted that soft coatings are, in general, not suitable for use in association with cathodic protection.

Contents

Section 1
General

1.1 Application

1.1.1 The Chapters in this Part outline the structural design requirements of ship and barge type units, built in reinforced and/or pre-stressed concrete. The design for other types of floating concrete units will be specially considered, although the general principles given in this Part are applicable. The general requirements for structural unit types in *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength* are to be complied with as applicable.

1.1.2 This Part only considers the design requirements for the concrete structure of the unit. The requirements of this Part are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.3 These Rules are intended primarily for units engaged in production and/or crude oil storage as defined in *Pt 3, Ch 3 Production and Storage Units*, to which reference should be made.

1.1.4 Special consideration will be given to units required for the storage of liquefied gas or liquid chemicals in bulk. The following technical aspects are to be considered in full for the storage of liquefied gas:

(a) selection of gas containment system;
(b) interaction between concrete structure and containment system;
(c) the effects of temperature on the concrete, *see Pt 9, Ch 4, 2.6 Freezing and thawing*;
(d) fixing/embedding the containment system supporting structure in concrete;
(e) arranging a moisture barrier where considered necessary.

1.2 Recognised Codes and Standards

1.2.1 These Rules give requirements for detailed design. Recognised Codes and Standards which give an equivalent level of safety will be considered but must be agreed by Lloyd's Register (LR) in each case.

1.3 Class notations

1.3.1 The Regulations for classification and the assignment of class notations are given in *Pt 1, Ch 2 Classification Regulations*, to which reference should be made.

1.3.2 In addition to the normal class notations which may be assigned to an installation, for concrete units a suitable descriptive note will be included in the *Offshore Register*, e.g. **concrete hull**.

1.4 Plans and data submission

1.4.1 Plans, calculations, data and specifications are to be submitted in accordance with *Pt 4, Ch 1, 4 Information required*as per steel structures, as applicable.

1.4.2 For units with process plant or drilling plant, the additional plans and information required by *Pt 3, Ch 7 Drilling Plant Facility* and *Pt 3, Ch 8 Process Plant Facility*, as applicable, are also to be submitted.

1.4.3 In addition to the above requirements, plans are to contain reinforcement and pre-stressing details for the whole concrete structure.

1.4.4 Calculations are also to be submitted for the serviceability and progressive collapse limit states in addition to the ultimate strength and fatigue calculations required in *Pt 4, Ch 1, 4.3 Calculations and data 4.3.1*.

Section 2
Design principles

2.1 Semi-probabilistic approach

2.1.1 These Rules for concrete structures assume the use of a semi-probabilistic analysis with characteristic values of loads and strengths of materials in association with partial safety factors. Departure from the partial safety factors or other design criteria given in these Rules is to be agreed with LR.

2.1.2 Other design approaches can be accepted, subject to approval.

2.2 Limit state design

2.2.1 The aim of this design method is the achievement of an acceptable probability that the structure or part of a structure being designed will not reach a particular state, called a limit state, in which it infringes one of the criteria governing its strength, durability or use.

2.2.2 The limit state categories are outlined in*Pt 9, Ch 1, 3 Limit states of design*. The required loads and load combinations are given in *Pt 9, Ch 2 Loads and Load Combinations* and structural design in *Pt 9, Ch 3 Structural Design*.

Section 3
Limit states of design

3.1 Ultimate Limit State (ULS)

3.1.1 The strength of the structure is to be sufficient to ensure that under the worst combination of wave loads, still water loads and mooring loads, the structure will not collapse, buckle or implode, *see also Pt 9, Ch 3, 4.2 Analysis of sections for ULS*.

3.1.2 Individual sections are to be checked for rupture. Consideration is also to be given to the mode of failure. In general, the initiation of failure of primary members by compression or shear is to be avoided.

3.2 Serviceability Limit State (SLS)

3.2.1 The serviceability limit is selected to ensure that the structure will meet the requirements for deflection, durability, liquid tightness and cracking under service conditions, *see also Pt 9, Ch 3, 4.3 Analysis of sections for SLS*.

3.2.2 The deflection of the structure or any part of the structure is to be limited such that it does not adversely affect the efficiency of the structure. Deflections are to be compatible with the degree of movement acceptable for the operation of services, etc. Any particular requirements should be specified by the Owner.

3.2.3 The durability of the structure is dependent upon the mix design, the concrete cover, control of cracking by the reinforcement, and exposure conditions. Requirements for concrete mix and cover are given in *Pt 9, Ch 4 Materials and Durability*.

3.3 Fatigue Limit State (FLS)

3.3.1 The designer is to demonstrate that the structure is not susceptible to fatigue failure. Agreement is to be reached with LR on the areas of the structure which are potentially vulnerable to fatigue. In particular, the oil storage tank area and the turret area are to be specially considered.

3.3.2 A fatigue analysis of critical areas is to be carried out based on the principle of cumulative damage, or fracture mechanics, *see also Pt 9, Ch 3, 4.4 Analysis of sections for FLS*.

3.3.3 The dynamic behaviour of the unit is to be investigated to determine whether the increase in load effects due to dynamic amplification is significant.

3.4 Accidental (ALS) and Progressive Collapse Limit State (PCLS)

3.4.1 The layout of the structure and the interaction between the structural members are to be such as to ensure a robust and stable design.

3.4.2 Consideration is to be given to redundancy and the possibility of progressive collapse. The designer must ensure that there is sufficient strength or redundancy to prevent this occurring. This requirement relates particularly to accidental or exceptional loads. Consideration is to be given to both the intact and post damaged condition.

3.4.3 Environmental return periods for use in post damaged conditions are given in *Pt 9, Ch 2, 2.4 Deformation loads 2.4.2*.

■ *Section 1* General

1.1 Application

1.1.1 For definitions of applied structural loads, methods of load calculation and load combinations, *see Pt 4, Ch 3, 4 Structural design loads*. The additional requirements for structural unit types defined in *Pt 4, Ch 4 Structural Unit Types* and *Pt 4, Ch 5 Primary Hull Strength*, as applicable, and the requirements of this Chapter are to be complied with.

■ *Section 2* Definitions

2.1 Permanent loads

2.1.1 The following can be considered permanent loads:

- Weight of structure.
- Weight of permanent ballast and equipment.
- Buoyancy to support permanent loads.

2.1.2 Any long-term reduction in buoyancy due to water absorption into the concrete should be considered. Similarly, any long-term increase in weight due to absorption of internal fluids such as oil or ballast water should also be considered.

2.2 Live loads

2.2.1 Live loads are related to the operation of the unit and can vary in magnitude. The following can be considered as examples:

- Pressure of liquid cargo and variable ballast.
- Mooring loads for the still water condition.
- Weight of stored materials and equipment.
- Loads associated with process operation.
- Crane and helicopter operations.
- Buoyancy to support live loads.

2.3 Environmental loads

2.3.1 The assessment of environmental loads may be based on the results of model tests or by suitable direct calculation of the actual loads on the hull at the specific location, taking into account the following service related factors:

(a) Site-specific environmental conditions.
(b) Mooring loads due to the environment.
(c) Weathervaning with wave loadings predominantly from one direction.
(d) Long-term service effects at a fixed location.
(e) Range of tank loading conditions.

2.3.2 The characteristic value of the environmental load for a given limit state is to be the most unfavourable value calculated for the specified environmental return period, *see Pt 9, Ch 2, 2.4 Deformation loads 2.4.2*.

2.3.3 In assessing the values for wave, wind and current in a given environmental return period event, allowance can be made for joint probability, provided this can be documented.

2.3.4 All external water pressures due to waves above the unit's maximum operating draught are to be considered as environmental loads.

2.3.5 Pressure heads due to wave impact loading at the fore end of concrete structures will be specially considered. In harsh environments a site-specific assessment is to be carried out to determine equivalent design pressure heads on the shell envelope. Where model tests are carried out, arrangements should be made to measure bow impact wave pressures, *see also Pt 4, Ch 3, 4.1 General 4.1.5*.

2.3.6 Loads from green seas on the deck and fore structure are to be considered as an environmental load. It is not necessary to include these loads in the overall bending moment for the hull strength, but they should be considered as a local ULS load on deck panels with the appropriate load factors. Minimum design deck pressures for this condition can be obtained from *Pt 4, Ch 7 Watertight and Weathertight Integrity and Load Lines*, except where model tests indicate higher loadings, *see also Pt 4, Ch 3, 4.1 General 4.1.5* and *Pt 10, Ch 1, 11 Green water and wave impact*.

2.3.7 All hydrostatic pressures due to waves and internal sloshing forces are to be considered as environmental loads.

2.4 Deformation loads

2.4.1 Deformation loads on the structure shall be considered. These can result from the following sources amongst others:

- Temperature.
- Creep.
- Shrinkage.
- Pre-stressing.

2.4.2 For concrete structures the effects of cargo temperatures relative to seasonal ambient temperatures are to be considered for both sea and air temperatures, as appropriate for the section being assessed.

Table 2.2.1 Basis for selection of return periods for environmental loads

Limit State / Load	ULS	SLS	FLS	PLS		
				Intact		Damage
				Accidental	Abnormal, *see* Note 5	*see* Note 4
Environmental (E)	100	S *see* Note 1	Exp *see* Note 2	10 000 *see* Note 3	10 000	10

Accidental (A)	–	–	–	10 000 *see* Note 3	–	–

NOTES

1.For SLS, two conditions are required to be assessed, *see Pt 9, Ch 3, 4.3 Analysis of sections for SLS*

(a)Normal serviceability – this is selected such that the environmental loads will not be exceeded more than 100 times in the design life of the structure. In the absence of a more detailed assessment, for a typical 25-year design life, actions may be assumed to be 60% of the characteristic load for a 100-year return period event.

(b)Modified serviceability – 100-year return period event.

2.Exp = Expected Load History.

3.The combined return period of occurrence for the environmental and accidental loads is not to be greater than 10 000 years. In practice, dropped objects and collision loads against the hull will normally cause only local damage and hence need not be combined with environmental loads.

4.Where the PLS intact analysis shows little or no damage, the PLS damage condition need not be investigated.

5.The abnormal event is not a requirement for class but may be required to be assessed by some national or coastal state authorities.

2.5 Accidental and abnormal loads

2.5.1 Accidental loads are defined in *Pt 4, Ch 3, 4.2 Definitions 4.2.4*and *Pt 4, Ch 3, 4.16 Accidental loads*. In addition, the failure of an oil cooling system, if fitted, is to be considered.

2.6 Characteristic value of loads

2.6.1 For the loads defined in this Section, the characteristic value of the individual loads are as follows:

Permanent – calculated value.
Live – calculated or specified value.
Environmental – most unfavourable value for specified return period, *see Pt 9, Ch 2, 3.1 Load factors and load combinations 3.1.3*.
Deformation and Accidental – specified value unless controlled by environmental considerations.

■ *Section 3* Load combinations

3.1 Load factors and load combinations

3.1.1 The general principles for load combinations for marine service are given in *Pt 4, Ch 3, 4.3 Load combinations 4.3.1*. Details of all load combinations for use with concrete structures, with the appropriate load factors, are given in *Pt 9, Ch 2, 3.1 Load factors and load combinations 3.1.3* for the various limit states.

3.1.2 The design load is usually taken as the characteristic load multiplied by the appropriate load factor. However, for floating structures it is necessary for the load factors to be such that each load combination considered is in equilibrium with regard to applied loads and buoyancy.

3.1.3 In addition to in-service load combinations, the design is to take into account loading conditions on the complete or partially complete structure during construction on a slipway or in a dock, launching, completion afloat, towing to site and anchoring to final position. Local environmental loads, appropriate to the season where applicable, are to be considered. The design for these conditions is to be such that the interim and subsequent compliance of the structure with the permanent design requirements is not impaired.

Table 2.3.1 Load factors and combinations for use with characteristics loads

Load Type	ULS		SLS	FLS	PLS Intact		PLS Post Damage
	(a)	(b)			Accidental	Abnormal	
Permanent (P)	1,3 *see* Note 1	1,0	1,0	1,0	1,0	1,0	1,0
Live (L)	1,3 *see* Note 1	1,0	1,0	1,0	1,0	1,0	1,0
Deformation (D)	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Pre-stressing (D)	1,1/0,9 *see* Note 3	1,1/0,9 *see* Note 3	1,0	1,0	1,0	1,0	1,0
Environmental (E) *see* Note 2	0,7	1,3	1,0	1,0	1,0	1,0	1,0
Accidental (A)	—	—	—	—	1,0	—	—

NOTES

1. These load factors are the minimum allowed and are to be consistent with the selected recognised Concrete Structural Code or Standard. Some Codes or Standards allow reduced factors for well defined hydrostatic loads. Both of these factors are to be 1,0 where this leads to more onerous conditions.

2. Return periods for environmental loads are to satisfy *Pt 9, Ch 2, 2.4 Deformation loads 2.4.2*.

3. Both coefficients are to be used in the analysis.

Section

■ Section 1 General

1.1 Structural design

1.1.1 The hull structure is to be capable throughout its design life, including construction and transit conditions, of withstanding all anticipated loads and deformations, both static and dynamic, with an adequate level of safety.

1.1.2 All relevant loads as defined in *Pt 9, Ch 2 Loads and Load Combinations* and *Pt 4, Ch 3 Structural Design*, *Pt 4, Ch 5 Primary Hull Strength* and *Pt 4, Ch 10 Steering and Control Systems* are to be considered and the effects of partial and/or non homogeneous loading in oil bulk storage tanks are to be considered.

1.2 Symbols

1.2.1 The symbols used in the various formulae in this Chapter are defined as follows:

A_c = area of concrete section

A_s = area of tension reinforcement

b = width of member

b_t = width of the section at the centroid of the tension steel

d = effective depth

d_e = effective tension zone (1,5 x cover + 10 bar diameters)

E_c = short-term elastic modulus of concrete

E_s = modulus of elasticity for steel

f_{cu} = characteristic compression strength of concrete, based on cube tests

f_{pu} = characteristic strength of pre-stressing tendon

f_{tk} = characteristic tensile strength of the concrete

f_{tm} = mean tensile strength of the concrete

f_y = characteristic tensile strength of reinforcement steel

h = overall depth of the member

w = water pressure in cracks

x = depth of neutral axis

γ_f = partial safety factor for load

γ_m = partial safety factor for strength of materials

ε_i = strain at the level considered, calculated ignoring the stiffening effect of the concrete in the tension zone

ε_m = average strain at the level where cracking is being considered.

■ *Section 2* Design requirements

2.1 Codes and Standards

2.1.1 Compliance with the various limit states given in *Pt 9, Ch 1, 3 Limit states of design* is to be based on analyses for the load combinations given in *Pt 9, Ch 2, 3 Load combinations*. The resulting concrete section checks are to meet the requirements of a recognised National or International Code or Standard for structural concrete, *see Pt 3, Ch 17 Appendix A Codes, Standards and Equipment Categories*, for recognised Codes and Standards.

2.1.2 Not all recognised Codes and Standards adequately address all of the following:

- Shell and panel members typical of offshore structures.
- Panels subjected to both in-plane and out of plane loads (transverse shear).
- Assessment of transverse shear and resistance in directions non-orthogonal to the main axes.
- Multi axial stress in concrete.
- Crack control and liquid tightness.
- The effects of water pressure in cracks and pores on the applied loads and resistance.
- Fatigue of concrete, reinforcement and shear steel.
- Second order effects including panel buckling.
- Discontinuity regions, including complex nodes.

Where the selected Code or Standard does not adequately address all the above areas of design, it should be supplemented by suitable alternatives as agreed by Lloyd's Register (LR).

2.2 Design loads and design strength of materials

2.2.1 The design loads for a given limit state are obtained by multiplying the characteristic loads defined in *Pt 9, Ch 2 Loads and Load Combinations* with the appropriate partial load factors given in *Pt 9, Ch 2, 3.1 Load factors and load combinations 3.1.3* in *Pt 9, Ch 2, 3 Load combinations*.

2.2.2 The characteristic strength of materials used in design is normally based on the compressive strength of the concrete, the yield or proof stress of the reinforcement or the ultimate strength of a pre-stressing tendon, below which not more than five per cent of all test results are expected to fall. The characteristic fatigue strength is normally based on the value below which not more than 2,5 per cent lie.

2.2.3 For analysis of sections, the design strength of steel for a given limit state is derived from the characteristic strength divided by the appropriate partial safety factor, γ_m. The factor (γ_m) is introduced to take account of differences between actual and laboratory values, local variations, and inaccuracies in assessment of the resistance of sections. It also takes account of the importance of the limit state being considered.

2.2.4 For analysis of sections, the design strength of concrete for a given limit state is derived from the *in situ* strength divided by the appropriate partial safety factor, γ_m. The *in situ* strength of the concrete is a function of the characteristic strength and is defined in the selected concrete structural Code or Standard.

2.2.5 It is vital that the material factor, γ_m , used in the design is consistent with the requirements of the selected concrete structural Code or Standard, for all materials and limit states.

Section 3
Analysis

3.1 General

3.1.1 The methods of analysis used in assessing compliance with the requirements of the various limit states are to be based on as accurate a representation of the behaviour of the structure as is practicable. The analysis that is carried out to justify a design can be broken into two primary stages: analysis of the structure and analysis of the sections.

3.1.2 For analysis of the whole or part of the structure, and to determine force distributions within the structure, the properties of materials may be assumed to be those associated with their characteristic strengths, irrespective of which limit state is being considered. For section analysis of elements, the properties of the materials are to be those associated with their design strengths to the limit state being considered.

3.2 Analysis of structure

3.2.1 The analytical model may be based on non-linear or linear elastic theory. Where linear elastic analysis is used, the relative stiffnesses of members may be based on any of the following:

- The concrete cross-section: this is the entire plain concrete cross-section, ignoring the reinforcement.
- The homogenous or gross section: this is the entire concrete cross-section, including the reinforcement on the basis of modular ratio.

A consistent approach is to be used for all elements of the structure.

3.2.2 When cracking, creep or other causes lead to significant redistribution of loads, this should be considered. Alternatively, plastic methods of analysis such as yield line analysis may be used.

3.2.3 Values for elastic moduli, Poissons ratio, coefficient of temperature expansion, etc. used in the analysis may be based on the selected Code or Standard or knowledge of similar concretes. The values used in the analysis should be confirmed with tests on the concrete mixes used on site.

3.3 Analysis of sections

3.3.1 The element section analysis should consider the requirements of *Pt 9, Ch 3, 2.1 Codes and Standards 2.1.2*.

3.3.2 The following are to be addressed for the section analysis:

- Appropriate stress strain relationship for materials.
- Allowable compressive and tensile concrete strength limits.
- Material factors.
- Crack width formulae.
- Watertightness criteria.
- Fatigue strength relationships.

Detailed requirements for these items are to be covered in the recognised Codes or Standards, but further requirements are given in *Pt 9, Ch 3, 4 Requirements for section analyses* for each of the limit states under consideration.

Section 4
Requirements for section analyses

4.1 General

4.1.1 Although recognising that the selected concrete Code or Standard will have requirements for acceptance of design and detailing for the various limit states, the additional items outlined in this Section should also be complied with.

4.2 Analysis of sections for ULS

4.2.1 The material partial factor, γ_m , for reinforcement and pre-stressing strand should not be less than 1,15, irrespective of the Code or Standard selected.

4.2.2 In assessing panel members for buckling, adequate allowance is to be made for local and global geometric tolerances. Panels are to be assessed for a hydrostatic head based on the maximum still water draught together with the maximum wave pressures.

4.2.3 When considering shear close to supports, favourable arch effects are to be ignored when fluid pressure is acting in the cracks.

4.2.4 Where the shear failure mechanism is not well defined, the design is to be based on principal tensile stresses.

4.2.5 It is acceptable to include the positive effects of both compressive axial load and pre-stress when calculating shear resistance. However, it is considered that shear cracking prior to the ULS should be avoided and the appropriate method of calculation is to be adopted.

4.2.6 Where in-plane deformation forces (excluding pre-stressing) enhance the transverse shear capacity, they should be neglected. This may necessitate performing shear checks both with and without certain deformation loads, e.g. temperature.

4.2.7 Where temperature effects are significant and/or where lightweight concrete is used, the coefficient of temperature expansion, $\propto$, should be obtained by testing.

4.2.8 If the loading pattern of the cargo can result in significant torsion, these effects should be considered in the design.

4.3 Analysis of sections for SLS

4.3.1 Particular attention is to be given to design, detailing and construction of the large concrete areas in the splash zone.

4.3.2 The following crack width limits assume a formula similar to CEB/FIP recommendations. Equivalence should be demonstrated where the method of calculating crack widths is significantly different from that assumed.

4.3.3 Based on the normal serviceability condition (as defined in *Pt 9, Ch 2, 3.1 Load factors and load combinations 3.1.3* in *Pt 9, Ch 2 Loads and Load Combinations*) the calculated crack widths should satisfy the requirements in *Pt 9, Ch 3, 4.3 Analysis of sections for SLS 4.3.3*. External to the hull, the splash zone should be considered to extend from 3,0 m below the lightship draught up to the deck level. For units subject to green seas on deck and frequent sea spray, the top deck surface should also be considered as the splash zone. The interior of ballast tanks are also to be designed on the same basis as the splash zone.

Table 3.4.1 Zonal crack width limits

	Crack width
Submerged zone	0,4 mm
Splash zone	0,2 mm
Atmospheric zone	0,4 mm

4.3.4 Allowance is to be made in the crack width calculations for deformation strains (temperature) to be concentrated at the cracked face of sections and increase the concrete crack width. The practice of using a strain twice the elastically calculated strain is acceptable.

4.3.5 For construction, transportation and installation, the crack widths shall not exceed 0,6 mm.

4.3.6 The minimum reinforcement quantities required to control cracking should be as given below, irrespective of the requirements of the selected Code or Standard. The calculations are for the area of reinforcement to be provided in each face and each direction:

(a) for concrete sections required to be watertight or oiltight:

$$A_s = \frac{f_{tm} + W}{f_y} b d_e$$

f_{tm}, f_y, w, b and d_e as defined in *Pt 9, Ch 3, 1.2 Symbols*

$0{,}2 < d_e < 0{,}5\,(h - x)$

(b) for other sections:

$$A_s = \frac{kA_c}{f_y}\left(f_{tk} + w\right)$$

k = 0,4 for $h \le 0{,}3$ m

k = 0,25 for $h \ge 0{,}8$ m

linear interpolation for 0,3 m < h < 0,8 m.

4.3.7 In areas of the structure adjacent to the sea which are intended to be watertight/oiltight, through thickness cracks are to be avoided under normal serviceability conditions. In general, this is to be achieved by strictly maintaining a 'no tension' criterion for in-plane membrane forces for this condition.

4.3.8 A 'modified' serviceability condition shall be analysed for the extreme environmental condition as detailed in Note 1(b) of *Pt 9, Ch 2, 2.4 Deformation loads 2.4.2* in *Pt 9, Ch 2 Loads and Load Combinations*. This is to ensure that:

(a) the hull in contact with either sea-water and/or oil is to be designed so that, under any combination of loading, no tensile membrane stresses of a magnitude sufficient to cause cracking across the full thickness of the section can occur. Some flexural tensile stresses, however, may be unavoidable, but these are acceptable providing a compression zone of at least 200 mm is maintained;

(b) for the extreme environmental condition, the stress in the reinforcement is to be restricted to 0,85 f_y and the compressive stress in the concrete to 0,5 f_{cu} .

4.3.9 Details of minimum cover requirements are given in *Pt 9, Ch 4, 2.7 Concrete cover reinforcement*.

4.4 Analysis of sections for FLS

4.4.1 All stress variations imposed on the structure during its design life are to be considered in the fatigue evaluation. Account should be taken of the range of operating draughts and cargo filling/emptying cycles if significant.

4.4.2 A fatigue evaluation is to be carried out for the critical areas of the structure. It is expected this will be based on linear cumulative damage (Palmgren – Miner's Rule). The material partial factors and characteristic fatigue strength relationships (S-N curves) are to be appropriate for the selected Code or Standard, and should account for air and water locations, stress state and reinforcement diameter.

4.4.3 The dynamic behaviour of the unit is to be investigated to determine whether the increase in load effects due to dynamic amplification is important. If dynamic effects are considered significant then a response analysis is to be carried out.

4.4.4 The fatigue life factors of safety required are given in *Pt 4, Ch 6, 5.7 Deck stiffening and supporting structure 5.7.2* in *Pt 4, Ch 6 Local Strength* and range from 1 to 10, depending on location in the unit, the ability to inspect or repair and the consequences of failure. The factors chosen are to be agreed for areas assessed.

4.4.5 Where large compression or compression/tension stress ranges occur (e.g. hull bottom), consideration is to be given to appropriate design and detailing. Confinement reinforcement is to be provided to ensure ductile behaviour. As far as practicably possible, cycling into the tension range should be avoided.

4.4.6 It should be demonstrated that the design and detailing of penetrations, openings and access ways consider the increased cyclic nature of loading on floating concrete units compared to fixed offshore structures.

4.5 Analysis of sections for PCLS

4.5.1 In general, for accidental or abnormal loads, it should be documented that the strength or the ductility of the structure is sufficient for the applied loads.

4.5.2 For impact and explosive loads, account can be taken of increased material strength and modulus in accordance with the selected Code or Standard.

■ *Section 5* Other considerations

5.1 Installation layout and safety

5.1.1 In general, production units with crude oil bulk storage tanks are to be designed so that the separation of living quarters, storage tanks, machinery rooms, etc. are arranged in accordance with the requirements of *Pt 3, Ch 3 Production and Storage Units*.

5.1.2 Special consideration may be given to concrete oil storage tanks fitted with suitable partial tank linings to prevent the risk of the escape of gas into adjacent spaces.

5.1.3 Concrete storage tanks used for the storage of liquefied gases, with or without insulation, are to be specially considered.

5.1.4 The general requirements for fire safety, hazardous areas and ventilation are to comply with *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*. Safety and communication systems are to comply with the requirements of *Pt 7, Ch 1 Safety and Communication Systems*.

5.2 Fire resistance

5.2.1 The required minimum period of fire resistance is to be stated in the design brief so that adequate protective measures may be taken by the selection of appropriate aggregates, reinforcement and cover. The selected Codes or Standards or specialist literature should be referred to for guidance.

5.2.2 Care should be exercised with certain lightweight aggregates. Where necessary the fire resistance of lightweight concretes is to be documented.

5.3 Corrosion protection

5.3.1 The requirements for the corrosion protection in Part 8 applicable to steel structures is also to apply to the exposed steel components of concrete units.

5.3.2 Reinforcement steel and pre-stressing tendons should either be actually isolated from the protected external steel, or the cathodic protection system designed to allow for current drain into the reinforcement as if it were electrically linked. In view of the practical problems of electrically isolating exposed and embedded steel, it is often preferable to consider them linked and make the necessary allowances in the cathodic protection.

5.4 Watertight/weathertight integrity

5.4.1 The general requirements for watertight and weathertight integrity given in*Pt 4, Ch 8 Welding and Structural Details* are to be complied with.

5.4.2 Any proposals to deviate from the general requirements for steel units will be subject to special consideration.

5.5 Survey

5.5.1 The general requirements for surveys are to comply with*Pt 1, Ch 2, 3 Surveys — General*and *Pt 1, Ch 3 Periodical Survey Regulations*.

5.5.2 The Owner's planned procedure for the inspection of oil storage tanks and other enclosed spaces will be specially considered. Due account may be taken of the good performance to date of the use of concrete structures for the storage of hydrocarbons.

Section

■ *Section 1* Materials

1.1 General

1.1.1 Tests are to be made on all proposed materials prior to construction. The tests are to be carried out by an independent laboratory which is acceptable to Lloyd's Register (LR). Appropriate trials on proposed concrete and grout mixes will also be required. The testing is generally to be carried out in accordance with recognised National Codes or Standards, and is to be agreed with LR.

1.1.2 Certificates are to be submitted for all materials before work commences on site.

1.2 Cement

1.2.1 The following types of cement are acceptable:

- Ordinary Portland Cement.
- Rapid Hardening Portland Cement.
- Sulphate Resisting Cement.
- Low Heat Portland Cement.
- Portland Blast Furnace Cement.
- Portland Pozzalana Cement.
- Portland Pulverised Fuel Ash Cement.

1.2.2 The cement is to comply with the requirements of these Rules and with recognised National Codes or Standards. High-alumina cement is not to be used.

1.3 Cement replacements

1.3.1 Cement replacements, such as ground granulated blast furnace slag (g.g.b.f.s), pulverised fuel ash (p.f.a) or silica fume may be combined with Ordinary Portland Cement.

1.3.2 The proportions of the blend and the blended product itself are to comply with recognised National Codes or Standards. In particular circumstances blended proportions outside the range of normal Code requirements may be agreed with LR.

1.3.3 The percentage of silica fume in a blend is to be limited to 10 per cent by weight of cement.

1.4 Tricalcium aluminate

1.4.1 In order to limit potential sulphate attack, the tricalcium aluminate (C_3A) content of the cement is, in general, to be limited to 8 per cent, but in no case is it to exceed 10 per cent. The minimum C_3A content is to be 5 per cent.

1.5 Aggregates

1.5.1 Coarse and fine aggregates may be uncrushed and/or crushed natural and/or artificial mineral substances with particle sizes, shapes and other properties which have been accepted for use by testing and experience.

1.5.2 Marine aggregates are acceptable provided that the chloride salt content is at an acceptable level and the aggregate has a sufficiently low shell content. The total chloride content of the concrete mix arising from the aggregate, together with that from any admixtures and from any other source, is not to exceed 0,1 expressed as a percentage relationship between chloride ion and mass of cement in the mix.

1.6 Alkali-silica reaction

1.6.1 Some aggregates may be susceptible to deleterious reaction with alkalis normally present in the cement or from other sources including sea-water; this produces an expansive reaction which can cause cracking and disruption of the concrete.

1.6.2 It is recommended that, in order to minimise the risk of alkali-silica reaction, an aggregate of good performance record be used. Where this is not possible all aggregates are to be tested for potential reaction. The choice of aggregate is to be approved by LR and highly reactive aggregates will not be acceptable for use in sea-water. In some cases the aggregate will be acceptable if the following course of action is taken:

(a) Use of a low alkali (less than 0,6 per cent equivalent Na_2O) Portland Cement.

(b) Limit the alkali content of the concrete mix to 3 kg/m_3 of Na_2O equivalent.

(c) The use of g.g.b.f.s and p.f.a is recommended in some National Codes or Standards for reducing the alkali content of the mix. Agreement on their use will be subject to special consideration by LR and will also depend on the results of current test programmes.

1.7 Lightweight aggregate

1.7.1 Lightweight aggregates may be used, but the suitability of the aggregate selected for use is to be demonstrated.

1.8 Water

1.8.1 Water is to be clean and free from harmful matter, and is also to comply with National Codes or Standards. Seawater is not to be used as mixing or curing water for any concrete containing reinforcement or pre-stressing tendons.

1.9 Admixtures

1.9.1 Air-entraining agents, workability agents and retarding agents may be used. The effects of over and under dosage should be established. Calcium chloride is not to be used or any admixtures containing more than 0,1 per cent chloride ion.

1.10 Reinforcing steel

1.10.1 Reinforcement is to comply with an appropriate recognised National Code or Standard. Storage, bending and acceptable welding practices are also to be in accordance with an approved standard agreed with LR.

1.11 Pre-stressing tendons

1.11.1 Pre-stressing tendons are to comply with appropriate recognised National Codes or Standards. Handling and tensioning procedures are also to be agreed. The time periods between installing strands, tensioning and grouting are to be agreed.

1.12 Pre-stressing ducts

1.12.1 Rigid or semi rigid watertight ducting may be used. Suitable procedures are to be developed and approved by LR for ensuring that the ducts are placed correctly, are watertight and kept free of debris and concrete during construction.

1.13 Grout (for pre-stressing tendons)

1.13.1 Ordinary Portland Cement is preferred. Sea-water is not to be used. Admixtures should be free from products liable to damage the steel or grout itself, such as chlorides, nitrates or sulphides. Expanding agents based on aluminium may be used provided it has been demonstrated to LR's satisfaction that the particular dose rate does not lead to stress corrosion.

1.13.2 The mix is to have appropriate fluidity and bleed properties. These should be verified by trials. For high strength concrete (>65 MPa) consideration should be given to increasing grout strength above the 40 MPa normally achieved.

1.13.3 Grouting procedures are to be developed and approved by LR. For long tendons and 'U' tendons, etc. procedures are to be verified with a prototype trial.

Section 2
Durability

2.1 Zones of exposure

2.1.1 For durability, three zones of exposure are to be considered for concrete structures:

(a) Submerged zone: that part of the structure below the splash zone defined in item (b).
(b) Splash zone: all areas subject to wave action or sea spray, and is to be considered to extend 3,0 m below lightship draught and up to upper deck level, *see also Pt 9, Ch 3, 4.3 Analysis of sections for SLS 4.3.3*.
(c) Atmospheric zone: that part of the structure above the splash zone.

2.2 Cement content

2.2.1 A minimum content of 400 kg/m^3 is to be used for the splash zone. In the submerged and atmospheric zones the minimum cement content is to be 320 kg/m^3 where the maximum size of aggregate is 40 mm, or 360 kg/m^3 where the maximum size of aggregate is 20 mm.

2.2.2 Cement contents in excess of 500 kg/m^3 should generally not be used.

2.3 Water/cement ratio

2.3.1 The water/cement ratio is to be below 0,45 in the submerged zone and below 0,4 for the splash zone (defined in*Pt 9, Ch 3, 4.3 Analysis of sections for SLS 4.3.3*) and in the boundaries of oil storage tanks.

2.4 Minimum concrete strength

2.4.1 The minimum acceptable concrete strengths are indicated in *Pt 9, Ch 4, 2.5 Temperature 2.5.3*.

2.4.2 Concrete tensile strength is also to be measured where required by the design Codes or Standards. For high performance concrete, direct tensile tests should be adopted.

2.5 Temperature

2.5.1 Consideration is to be given to the heat of hydration and shrinkage that may cause cracking.

2.5.2 In cold weather, precautions should be taken to prevent frost damage to the concrete.

2.5.3 Procedures are to be developed and agreed for hot weather concreting (ambient temperature >30°C) and cold weather concreting (ambient temperature <5°C) where applicable.

Table 4.2.1 Minimum acceptable concrete strength

Zone	Exposure conditions	Concrete strength N/mm^2
Submerged	Directly exposed to salt water	40
	Directly exposed to crude oil or subject to severe abrasion	50
Splash	Directly exposed to salt water or salt-water spray	40
Atmospheric	Directly exposed to marine atmosphere	40
	Protected from direct exposure to marine atmosphere	30

NOTES

1. Concrete strength refers to the characteristic concrete strength obtained from testing standard 150 mm cubes of concrete at an age of 28 days.

2. The use of age factors is to be justified by testing.

2.6 Freezing and thawing

2.6.1 Parts of the structure that are subjected to freezing and thawing are to have adequate frost resistance. For severe situations, air entrainment is to be used, and reference is to be made to relevant standards for details of quality of air and spacing factors.

2.6.2 Freeze/thaw cycles may require special consideration for the storage of LPG and LNG in bulk depending upon tank arrangements and/or heating systems.

2.7 Concrete cover reinforcement

2.7.1 The nominal cover is to be not less than that shown in *Pt 9, Ch 4, 2.7 Concrete cover reinforcement 2.7.3* or in accordance with the following, whichever is the greater:

(a) 1,5 times the nominal maximum size of aggregate.
(b) 1,5 times the maximum diameter of reinforcement or pre-stressing tendons.
(c) For bundled bars, the greater of either 1,5 times the diameter of the largest bar in the bundle or the diameter of the equivalent bar, but not more than 100 mm. The equivalent bar is a single bar having the same cross-sectional area as the bundle of bars.

2.7.2 For the concrete given in this Section, the permeability is to be less than 10^{-12} m/sec.

2.7.3 For certain types of structural configuration additional cover may be required to prevent deterioration due to acidic water or hydrogen sulphide gas.

Table 4.2.2 Nominal concrete cover in relation to zones of exposure

Zone	Nominal cover, mm, *see* Note	
	Reinforcement	Pre-stress
Submerged	40	85
Splash	50	95
Atmospheric (subjected to spray)	50	95
Atmospheric (general)	40	85
NOTE Nominal cover is defined as the cover to the shear reinforcement.		

2.8 Concrete protection against chemical attack

2.8.1 For oil storage tanks, the possible attack by hydrogen sulphide, organic acids, etc. is to be considered.

2.8.2 Where flue gases are used as the inerting medium in tanks, consideration is to be given to the concrete being attacked by CO_2 and/or SO_2 in hot, high humidity conditions. This will need to be addressed on a case-by-case basis.

2.8.3 Where sufficiently high concentrations of chemicals may occur which could result in chemical attack, consideration is to be given to providing a suitable chemical resistant liner or partial liner.

Contents

■ *Section 1* General

1.1 Application

1.1.1 This Chapter outlines the hull structural design requirements of ship units with hull construction in steel engaged in production and/or cargo storage/offloading while permanently moored at offshore locations. For the purposes of this Part, the term 'cargo' refers to crude oil, liquefied gas, condensate, methanol, process chemicals including refrigerants and by-products of the production process.

1.1.2 The Rules are also applicable to units which normally operate while moored at offshore locations, but which are disconnectable in order to avoid extreme environmental conditions or hazards, *see also Pt 4, Ch 3, 4 Structural design loads*.

1.1.3 Units which operate as shuttle tankers will normally be assigned class in accordance with the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.1.4 Hull strength, scantlings and arrangements for ship units are to comply with *Pt 10 SHIP UNITS*. Reference is also made to the LR ShipRight Procedure for Ship Units.

1.1.5 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of this Chapter and the additional requirements related to the design arrangements and functions of drilling and production units given in *Pt 3, Ch 2 Drilling Units* and *Pt 3, Ch 3 Production and Storage Units* are to be complied with.

1.1.6 The scantlings and arrangements of units with a limited number of tanks for the storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered.

1.1.7 The class notations and descriptive notes applicable to units classed in accordance with these Rules are to be in accordance with *List of abbreviations* and*Pt 3, Ch 3, 1 General*, to which reference should be made.

1.1.8 Additional requirements related to the design function of the unit are given in *Pt 3 FUNCTIONAL UNIT TYPES AND SPECIAL FEATURES*.

1.1.9 Turret structures, mooring arms and yoke structures, etc. are to comply with the requirements of *Pt 10, Ch 1, 9 Mooring structure* and*Pt 3, Ch 13 Buoys, Deep Draught Caissons, Turrets and Special Structures*.

1.1.10 Units with a process plant facility which comply with the requirements of *Pt 3, Ch 8 Process Plant Facility* will be eligible for the assignment of the special features class notation **PPF**.

1.1.11 Units with a drilling plant facility which comply with the requirements of *Pt 3, Ch 7 Drilling Plant Facility* will be eligible for the assignment of the special features class notation **DRILL**.

1.1.12 The structural design of integral tanks for the storage of condensates is to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. The density of the condensate is not to be taken as less than the minimum density values, as defined in*Pt 10, Ch 2, 1.2 Definitions 1.2.3* in *Pt 10, Ch 2 Loads and Load Combinations*, for strength and fatigue assessments.

1.1.13 The structural design of integral tanks for the bulk storage of liquid chemicals is to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. The following requirements are also to be complied with:

(a) The density of the liquid chemicals is not to be taken as less than the minimum density values, as defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.3* in *Pt 10, Ch 2 Loads and Load Combinations*, for strength and fatigue assessments.
(b) Consideration is to be given to the nature of the chemicals being stored, including their corrosiveness, reactivity and flammability. Arrangements are in general to comply with the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (*IBC Code - International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in BulkAmended by Resolution MEPC.225(64)*), as interpreted by LR.
(c) Corrosion rates will be specially considered on the basis of the corrosiveness and reactivity of the stored chemical with the tank material.

1.1.14 The structural design of independent tanks for the bulk storage of liquid chemicals is to comply with the requirements of *Pt 11, Ch 4 Cargo Containment* and *Pt 10, Ch 1, 1.1 Application 1.1.13* and *Pt 10, Ch 1, 1.1 Application 1.1.13*.

1.1.15 Ship units engaged in the production, storage and offloading of liquefied gases at a fixed location are to comply with *Pt 11 PRODUCTION, STORAGE AND OFFLOADING OF LIQUEFIED GASES IN BULK* and other relevant Parts in addition to the requirements of this Part.

1.2 Definitions

1.2.1 General definitions are given in *Pt 1, Ch 2, 2 Definitions, character of classification and class notations* and *Pt 4, Ch 1, 5 Definitions*.

1.2.2 Additional definitions relevant to *Pt 10 SHIP UNITS* are given below:

$T_{\rm sc}$ = deep load draught, in metres, is the maximum draught on which the scantlings are based

$T_{\rm LT}$ = light load draught, in metres, is the minimum draught on which the scantlings are based.

1.2.3 **Moderate service**. A Moderate service is one where the site-specific responses of the vessel are less than or equal to the responses in unrestricted worldwide transit. The following responses are to be compared:

(a) Hull girder vertical wave bending moment.
(b) Relative wave elevation.
(c) Vertical acceleration.
(d) Roll angle.

Harsh service. A Harsh service is one which does not satisfy the definition of a Moderate service.

Transit. Any voyage of the unit, self-propelled or unpropelled, from one geographical location to another. The following are considered transit conditions:

(a) **Delivery voyage**. Delivery voyage of a unit along a defined route from a shipyard or field to the operating site at which the **OI** class notation is assigned. The delivery voyage is typically scheduled for restricted sea states.
(b) **Restricted service area transit**. Transit of a unit at any time across a restricted service area. Voyages of this nature may be carried out by disconnectable units that sail away within a defined service area either to avoid approaching heavy weather and/or to return to a dry dock for inspection.
(c) **Unrestricted worldwide transit**. Transit of a unit at any time across any sea area in the world. Voyages of this nature may be carried out by disconnectable units that sail away either to avoid approaching heavy weather and/or to return to a dry dock for inspection.

1.3 Application of transit conditions

1.3.1 All units are to be assessed for the delivery voyage. This is to ensure that the unit arrives fit for entry into class at the operating field where the **OI** class notation is assigned. The Owner is to define the wave environment and the maximum transit speed for the delivery voyage.

1.3.2 Disconnectable units are to be assessed for unrestricted worldwide transit, in which case the delivery voyage need not be assessed. The Owner is to define the maximum transit speed for disconnected service. For unrestricted worldwide transit, the loads defined in *Pt 10, Ch 2, 7 Environmental loads for unrestricted worldwide transit condition* are to be used. Alternatively, at the request of the Owner, the unit may be assessed to transit within a restricted service area. In this case, a service restriction will be placed on the unit and recorded in the class notation, *see Pt 10, Ch 1, 1.2 Definitions 1.2.5*. The Owner is to define the wave environment for the restricted service area.

1.4 Application of acceptance criteria

1.4.1 In general, the Working Stress Design (WSD) method is applied for the assessment of the scantlings in *Pt 10, Ch 3 Scantling Requirements*. Three sets of acceptance criteria are given that are dependent on the probability level of the characteristic combined loads.

1.4.2 The acceptance criteria set AC1 is applied when the combined characteristic loads are frequently occurring, typically for the static design load combination. This means that the loads occur on a frequent or regular basis. The allowable stress for a frequent load is lower than for an extreme load and takes into account allowance for some dynamics and operational mistakes.

1.4.3 The acceptance criteria set AC2 is typically applied when the combined characteristic loads are extreme values, e.g. typically for the static + dynamic design load combinations. High utilisation of the structural capacity is allowed in such cases because the considered loads are extreme loads with a low probability of occurrence.

1.4.4 The acceptance criteria set AC3 is typically applied for capacity formulations based on plastic collapse models such as those that are applied to address bottom slamming and bow impact loads.

■ *Section 2* Information required

2.1 General

2.1.1 Sufficient plans and supporting data are to be submitted to enable the design of the structure to be assessed. The plans are also to be suitable for use during construction, survey and inspection/maintenance of the unit.

2.1.2 Plans are to be submitted in triplicate, but generally only one copy of supporting design documentation and calculations is required. Plans and supporting documentation should be submitted and approved prior to commencement of construction.

2.1.3 Plans are to contain all necessary information fully to define the structure, including construction details, materials, welding and loads imposed on the structure by equipment and systems, as appropriate.

2.1.4 A copy of the Construction Booklet, Operations Manual and In-Service Inspection Plan must be submitted for class approval, incorporating the final approved revisions of relevant plans and documentation, *see Pt 1, Ch 3, 1.6 Planned survey programme* and *Pt 3, Ch 1 General Requirements for Offshore Units*.

2.1.5 Plans are to include information related to the renewal thickness as specified in *Pt 10, Ch 1, 13 Steel renewal criteria*.

2.1.6 A general list of plans and supporting calculations is given in *Pt 10, Ch 1, 2.2 Plans and supporting calculations*. Detailed plan lists can be found in the relevant Sections of the Rules listed below:

- *Pt 3, Ch 1, 5 Information required*, (Rules for Ships): Basic Hull structure;
- *Pt 1, Ch 3, 1.6 Planned survey programme*: Planned survey programme;
- *Pt 3, Ch 1, 2 Information required*: General, OIWS, Construction Booklet;
- *Pt 3, Ch 3, 1 General*: Production and oil storage units (general);
- *Pt 3, Ch 3, 2.1 Plans and data submission*: Production and oil storage units (structure);
- *Pt 3, Ch 8, 1.1 Application*: Process plant facility;
- *Pt 3, Ch 9, 1.3 Information and plans required to be submitted*: Dynamic positioning system;
- *Pt 3, Ch 10, 1.4 Plans and data submission*: Positional mooring system;
- *Pt 4, Ch 1, 4 Information required*: General structure;
- *Pt 4, Ch 6, 5.2 Plans and data*: Helideck;
- *Pt 4, Ch 7, 1.2 Plans to be submitted*: Watertight/weathertight integrity;
- *Pt 8, Ch 1, 3 Plans and information*: Corrosion control.

2.2 Plans and supporting calculations

2.2.1 In general, plans covering the following items are to be submitted:

(a) main scantling plans:

- midship section showing longitudinal and transverse structural members;
- construction profiles/plans showing all main longitudinal structural elements along the unit's length;
- shell expansion;
- main oil-tight and watertight transverse bulkheads including primary support members.

(b) loading guidance information:

- preliminary loading manual;
- final loading manual;
- details of the design basis;
- test conditions for the loading instrument.

(c) detailed construction plans:

- cargo tank construction plans showing the variations in detail arrangements and scantlings of transverse primary support members;
- fore end;
- aft end;
- machinery spaces;
- deck-houses and superstructures;
- helideck;
- ice strengthening;
- materials and grades;
- plans showing the proposed fatigue factors of safety for each part of the structure.

(d) detail design plans, except where the information is already included on plans listed in *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1* and *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1*:

- hull penetration plans;
- welding;
- bilge keels;
- booklet of standard design details;
- pillar and girder support arrangements for decks;

- access arrangements;
- details and arrangements of openings and attachments to the hull structure for means of access for inspection/maintenance purposes.

(e) plans detailing support structures, except where the information is already included on plans listed in *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1* to *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1*:

- masts, derrick posts, cranes and crane pedestals, flare towers and heavy equipment;
- towing equipment;
- other deck equipment or fittings;
- machinery seatings;
- riser support structures;
- rudder stock, tiller and steering nozzles;
- stern frame and propeller brackets.

(f) The following supporting documents are to be submitted:

- general arrangement;
- capacity plan;
- lines plan or equivalent;
- dry-docking plan, where developed;
- freeboard plan or equivalent, showing freeboards and items relative to the conditions of assignment;
- corrosion control scheme;
- towing and anchoring arrangements;
- watertight subdivision;
- welding procedures.

2.3 Plans and information to be supplied on board the unit

2.3.1 One copy of each of the following documents:

(a) main scantling plans, as given in *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1*;
(b) one copy of the final approved loading manual;
(c) one copy of the final loading instrument test conditions;
(d) detailed construction plans, as given in *Pt 10, Ch 1, 2.2 Plans and supporting calculations 2.2.1*;
(e) welding;
(f) details of the extent and location of higher tensile steel, together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels;
(g) details and information on use of special materials, such as aluminium alloy, used in the hull construction;
(h) details of the corrosion control system;
(i) operations manual.

Plans are to indicate the new-building and renewal thickness for each structural item.

■ *Section 3* **Materials**

3.1 General

3.1.1 Steel should be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) or other acceptable standards. The strength and grades (notch toughness) of steel required will depend on the following:

(a) design temperature;
(b) thickness;
(c) substance being stored/processed;

(d) structural category;

(e) location.

3.1.2 Material classes and steel grades should comply with *Pt 4, Ch 2 Materials* unless indicated otherwise in this Section. Materials for the hull structure of ship units engaged in the production, storage and offloading of liquefied gases at a fixed location are also to comply with *Pt 11, Ch 4 Cargo Containment* and *Pt 11, Ch 6 Materials of Construction and Quality Control* .

3.1.3 Critical joints which depend upon the transmission of tensile stress through the thickness perpendicular to the plate surface of one of the members are to be avoided wherever possible. Where these types of joints are unavoidable the through plate member should have suitable through thickness properties in accordance with *Pt 4, Ch 2, 4.1 General 4.1.3*.

3.1.4 Steel grades for special and primary structural components with thickness in excess of the limitations of *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* of the Rules for Materials and *Pt 4, Ch 2, 4.1 General 4.1.6* in *Pt 4, Ch 2 Materials* will be specially considered.

3.1.5 Where attachments/pads are located on special or primary components which are subjected to high stresses, the attachment is to be of the same material as the plating to which it is attached, with welding to the same standard as the main structure.

3.1.6 Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as normal strength hull structural steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel.

3.1.7 For the determination of hull girder section modulus, where higher strength hull structural steel is used, a higher strength steel factor, k, is given in *Pt 10, Ch 1, 3.1 General 3.1.7*.

Table 1.3.1 Values of k

Specified minimum yield stress, N/mm^2	k
235	1,00
265	0,93
315	0,78
340	0,74
355	0,72
390	0,68
NOTE Intermediate values are to be calculated by linear interpolation.	

■ *Section 4*
Structural arrangement

4.1 General

4.1.1 General requirements regarding location and separation of spaces, layout and arrangement of primary structural components are given in *Pt 3, Ch 3, 1.4 Installation layout and safety*. Detailed requirements are given in *Pt 10, Ch 1, 4 Structural arrangement*.

4.1.2 Overall subdivision of the hull should take full account of strength and stability requirements and minimise the consequences of damage, pollution risk and loss of the unit in the event of damage. Additional subdivision of the hull may be required to account for ballast water needed to control hull stresses and for the storage of process-related liquids.

4.1.3 The Marine Environment Protection Committee of the International Maritime Organization (IMO) has decided that tankers which are used solely for storage and production of oil, and are moored at a fixed location except in extreme environmental or emergency conditions, are not required to comply with all the provisions of the *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto (hereinafter referred to as *MARPOL*) unless specified in whole or in part by the relevant National Authority. Therefore, double hulled construction would not be necessary

unless specified by the National Authority. When *MARPOL* is invoked for ship units, normally also the interpretations for ship units defined in MEPC Circ. 139(53) are applicable, but this is subject to adoption of MEPC Circ.139 by the National Authority.

4.1.4 Account should be taken of the interaction between structural strength and stability. Particular consideration should be given to tank dimensions with respect to tank inspection/ maintenance requirements and sloshing/free surface effects for partially filled tanks. Intact and damage stability should comply with applicable National Authority requirements.

4.1.5 Self-propelled floating units should meet the requirements of the *International Convention on Load Lines 1966* (hereinafter referred to as ICLL). Units which do not engage in international voyages, except for transfers between fabrication sites and the installation voyage to the designated site, should have marks which indicate the maximum permissible draught as calculated under the ICLL Requirements.

4.1.6 General requirements for deck layouts/ arrangements are given in *Pt 3, Ch 3, 1.4 Installation layout and safety* and *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE*.

4.1.7 Deck-house superstructures may be located forward or aft of the cargo storage tanks. Living quarters, lifeboats and other means of evacuation should be located in non-hazardous areas and be protected and separated from production, storage and turret areas. As a minimum, the arrangement and separation of living quarters, storage tanks, machinery rooms, etc. should be in accordance with the *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978 (hereinafter referred to as SOLAS). Where the superstructure is located forward of the cargo tank area, arrangements should provide a suitable level of separation and protection.

4.1.8 The location of the topsides facilities deck and structural arrangements should comply with *Pt 3, Ch 3, 3.1 General 3.1.4*, Pt 3, Ch 3,7 and Ch 3,8 and *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE* as relevant, together with applicable National Authority Codes and Standards regarding dangerous zones or divisions and provision of adequate access. Areas and compartments of floating units are defined as hazardous zones according to their proximity to equipment, pipes or tanks containing certain flammable liquids and whether these fluids are at temperatures approaching or exceeding their flashpoints, *see Pt 7, Ch 2 Hazardous Areas and Ventilation*.

4.1.9 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration, taking into account any relevant National Authority requirements.

4.1.10 Reference should also be made to SOLAS and applicable amendments.

4.1.11 The number of openings in watertight bulkheads is to be kept to a minimum. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc. arrangements are to be made to maintain the watertight integrity.

4.2 Arrangement for internal turrets

4.2.1 A cofferdam or equivalent is to be arranged between cargo bulk storage tanks and the bulkheads bounding the turret well space or turret equipment spaces internal to the hull. The scantlings and testing requirements are to comply with Rule requirements for cofferdam bulkheads. Suitable corrosion protection, drainage and gas freeing arrangements are to be provided to such spaces. A pump-room, void space or water ballast tank will be accepted in lieu of a cofferdam.

4.2.2 The bulkheads bounding the turret well space are to comply with the scantling requirements for side shell structure and for bulkheads. Blast loading is also to be considered.

4.3 Structural continuity

4.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

4.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

Section 5
Structural design – New-build units

5.1 General

5.1.1 This Section outlines the hull structural calculation and analysis requirements for new-build ship units engaged in production and/or oil storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units.

5.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in *Pt 4, Ch 3 Structural Design* are to be considered, including the effects of partial and/or non-homogeneous loading in cargo bulk storage tanks. When considering the design loading conditions, the Owner/ designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, towing/ transportation should be considered, as applicable. Reference is also made to the LR ShipRight Procedure for Ship Units.

5.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the sitespecific location, taking into account the following service-related factors:

(a) site-specific environmental loads including relevant nonlinear effects;
(b) mooring system and riser loads;
(c) unit orientation and wave loading directions;
(d) long-term service effects at a fixed location;
(e) range of tank loading conditions, including empty tanks required for on-station surveys;
(f) potential relocations if applicable.

5.1.4 For Moderate service, the site-specific loads can be used. The loads for unrestricted worldwide transit from *Pt 10, Ch 2 Loads and Load Combinations* may be used at the Owner's discretion. For Harsh service the site-specific loads must be used. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied. Where the **ShipRight RBA** notation is assigned, the site-specific loads must be used.

5.1.5 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in *Pt 1, Ch 2 Classification Regulations*. For design purposes, the permissible still water bending moments and shear forces for tank inspection/maintenance conditions may be based on 100-year return period seasonal site criteria. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

5.1.6 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

5.1.7 Disconnectable units, as defined in *Pt 10, Ch 1, 1.1 Application 1.1.2*, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

5.1.8 The hull structure of is to be assessed for applicable transit conditions in accordance with *Pt 10, Ch 1, 1.3 Application of transit conditions*.

5.1.9 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*. Collision loads against the hull structure will normally cause only local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

5.1.10 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

5.1.11 Hull integration structure in way of moorings, topsides and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with *Pt 10, Ch 3 Scantling Requirements* or *Pt 4, Ch 5 Primary Hull Strength*, .

5.1.12 Where permitted by the relevant National Authority, single hulled units may be accepted.

5.1.13 Sufficiently robust underdeck reinforcement should be provided in the way of the welded connections of the topsides support structure to the main hull. The support structures should be aligned with the primary members of the hull structure.

5.1.14 Hull structure and mooring integration structures: for disconnectable units at locations exposed to cyclones, the environmental loads when disconnected are not to be taken less than required by *Pt 10, Ch 2 Loads and Load Combinations* for unrestricted worldwide transit.

5.2 Hull scantlings

5.2.1 The longitudinal strength of the unit is to comply with the requirements of *Pt 10, Ch 3 Scantling Requirements*. The total stresses from the combined effects of site-specific wave loads, still water loads, mooring loads, etc. are not to exceed permissible values.

5.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted worldwide transit, the site-specific values may generally be used for design, *see Pt 10, Ch 1, 5.1 General 5.1.4*. However, in no case are the sitespecific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted worldwide transit.

5.2.3 The requirement for hull girder inertia given in *Pt 10, Ch 3 Scantling Requirements* is to be complied with.

5.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

5.2.5 For initial design purposes, site-specific environmental factors are given in *Pt 10, Ch 2, 3.3 Environmental factors* with the associated Dynamic Load Combination factors (DLCF) given in *Pt 10, Ch 2, 7 Environmental loads for unrestricted worldwide transit condition* for the unrestricted worldwide transit condition and *Pt 10, Ch 2, 8 Environmental loads for site-specific load scenarios* for the On-site Operational condition.

5.2.6 For the final design, the loads derived in accordance with the LR ShipRight Procedure for Ship Units must be used.

5.3 Strength analysis

5.3.1 The scantlings of the primary structure of the cargo bulk storage tank area are to be verified by direct calculations based on a three-dimensional finite plate element analysis carried out in accordance with the LR ShipRight Procedure for Ship Units.

5.3.2 The corrosion additions are to be determined as described in *Pt 10, Ch 1, 12 Corrosion additions*.

5.4 Fatigue analysis

5.4.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with the LR ShipRight Procedure for Ship Units.

5.4.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading, *see also Pt 4, Ch 5, 5.2 Fatigue life assessment*.

5.4.3 Fatigue calculations for the mooring structures and integration of the mooring system within the unit's hull structure are also to be carried out, *see Pt 3, Ch 10 Positional Mooring Systems*.

5.4.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

5.4.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with *Pt 4, Ch 5, 5 Fatigue design*.

5.4.6 The minimum design fatigue life for structural elements should not be less than the intended field life, but in general should not be less than 25 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also Pt 4, Ch 5, 5 Fatigue design*.

Section 6
Structural design – Tanker conversions

6.1 General

6.1.1 This Section outlines the hull structural calculations and analysis requirements for tanker conversions engaged in production and/or cargo storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units. At the Owner's request, the requirements given in *Pt 10, Ch 1, 5 Structural design – New-build units* may be applied instead of the requirements given in this Section.

6.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in *Pt 4, Ch 3 Structural Design* are to be considered and the effects of partial and/or non-homogeneous loading in cargo bulk storage tanks are to be considered. When considering the design loading conditions, the Owner/designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, and towing/ transportation should be considered, as applicable. Reference is also made to the LR ShipRight Procedure for Ship Units.

6.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:

(a) Site-specific environmental loads including relevant nonlinear effects.
(b) Mooring system and riser loads.
(c) Unit orientation and wave loading directions.
(d) Long-term service effects at a fixed location.
(e) Range of tank loading conditions, including empty tanks required for on-station surveys.
(f) Potential relocations if applicable.

6.1.4 For Moderate service, the site-specific loads can be used. The loads for unrestricted worldwide transit service from *Pt 10, Ch 2 Loads and Load Combinations* may be used at the Owner's discretion. For Harsh service, the unit is to be reassessed as for a new build. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied. Where the **ShipRight RBA** notation is assigned, the sitespecific loads must be used.

6.1.5 Where a unit is intended to operate in Moderate Environments, the existing scantlings of the hull need not be re-assessed, subject to the following conditions:

- the vessel was built under the survey of a member of IACS before conversion;
- the vessel has been maintained in Class by a member of IACS before conversion;
- CAP assessment 1 or 2 assigned;
- all necessary repairs are made to delete any Conditions of Class;
- the in-service corrosion margins applied after conversion are the same as those applicable as a trading tanker;
- LR Transfer of Class (TOC) procedures are complied with if the vessel is transferring Class to LR;
- a Special Survey is conducted during the conversion;
- the loading on the structure is not increased;
- the structure is not changed;
- the vessel was originally approved for worldwide service.

Where these conditions are not met (for example, turret integration structure, supporting structure under topsides and crane pedestals), the structure is to be re-assessed in accordance with *Pt 10, Ch 1, 5 Structural design – New-build units*.

6.1.6 For Moderate service further to the reassessment criteria specified in *Pt 10, Ch 1, 6.1 General 6.1.5*, the hull scantlings are to be reassessed where the **ShipRight RBA** notation is assigned. If the structure is modified or the loading changed then the hull scantlings affected by these changes should be reassessed. Hull scantlings of a conversion may need to be reassessed for the following reasons:

- integration of the mooring system of an internal turret;
- loads from topsides equipment on the upper deck;
- redefinition of loading limitations assigned as a tanker (for example, changes to permissible still water bending moments and shear forces) where required for unit-specific loading conditions;

- measured corrosion found to be in excess of that permitted for a trading tanker.

6.1.7 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in *Pt 1, Ch 2 Classification Regulations*. For design purposes, the permissible still water wave bending moments and shear forces for tank inspection/ maintenance conditions may be based on the existing assigned permissible still water values. Where the existing assigned permissible still water values are insufficient, wave bending moments and shear forces may be based on 100-year return period seasonal site criteria and still water permissible values adjusted accordingly. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

6.1.8 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

6.1.9 Disconnectable units, as defined in *Pt 10, Ch 1, 1.1 Application 1.1.2*, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

6.1.10 The hull structure is to be assessed for applicable transit conditions in accordance with *Pt 10, Ch 1, 1.3 Application of transit conditions*.

6.1.11 The general requirements for investigating accidental loads are defined in *Pt 4, Ch 3, 4.16 Accidental loads*. Collision loads against the hull structure will normally cause only local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

6.1.12 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

6.1.13 Hull integration structure in way of moorings, topsides, crane pedestals, flare towers and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with *Pt 4, Ch 5 Primary Hull Strength*.

6.1.14 The detailed scope of analysis required for hull structural assessments of tanker conversions will be considered on a case-by-case basis, *see Pt 10, Ch 1, 6.2 Hull scantlings*.

6.1.15 Where permitted by the relevant National Authority, single hulled units may be accepted.

6.1.16 Sufficiently robust underdeck reinforcement should be provided in way of the welded connections of the topsides support structure to the main hull. Special attention should be given to alignment of primary members.

6.1.17 For disconnectable units at locations exposed to cyclones, the environmental loads when disconnected are not to be taken less than required by *Pt 10, Ch 2 Loads and Load Combinations* for unrestricted worldwide transit service for the assessment of structures required by *Pt 10, Ch 1, 6.1 General 6.1.6*.

6.1.18 For units permanently moored by the stern, the structural arrangements and scantlings of all exposed structure located in the aft end of the unit are to be specially considered. The strengthening of the bottom structure is to be specially considered.

6.2 Hull scantlings

6.2.1 Hull scantlings are to be re-assessed in accordance with the requirements for new-build units, *see Pt 10, Ch 1, 5.3 Strength analysis*, whenever any of the following apply:

(a) The unit is to be deployed in harsh service;
(b) The total hull girder bending moments (hogging and sagging) approved prior to conversion, i.e. vertical wave bending moment + permissible still water vertical bending moment, are exceeded; or
(c) The total hull girder shear forces (positive and negative) approved prior to conversion, i.e. vertical wave shear force + permissible still water vertical shear force, are exceeded.

6.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted worldwide transit, the site-specific values may generally be used for design, *see Pt 10, Ch 1, 6.1 General 6.1.4*. However, in no case are the sitespecific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted worldwide transit.

6.2.3 If the environmental factors, as defined in *Pt 10, Ch 1, 2.3 Plans and information to be supplied on board the unit*, calculated for the hull girder bending moments ($f_{\mathrm{Env-Mwv}}$ or $f_{\mathrm{Env-Mwv-h}}$) or shear force ($f_{\mathrm{Env-Qwv}}$) exceed 1,0, then the hull scantlings are to be re-assessed in accordance with the requirements for new-build units, *see Pt 10, Ch 1, 5.3 Strength analysis*.

6.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

6.2.5 Where the conversion includes provision for an internal turret mooring system, the effects of such openings and reinforcement structure on hull girder strength should be evaluated.

6.2.6 It is recommended that, in general, corrosion additions are to be determined based on *Pt 10, Ch 1, 12 Corrosion additions*; however, consideration will be given to alternative proposals submitted by the Owner.

6.3 Fatigue analysis

6.3.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with the LR ShipRight Procedure for Ship Units.

6.3.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading. *See also Pt 4, Ch 5, 5.2 Fatigue life assessment*.

6.3.3 Fatigue calculations for the mooring structure and integration of the mooring system within the unit's hull structure are also to be carried out, *see Pt 3, Ch 10 Positional Mooring Systems*.

6.3.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading, in accordance with *Pt 4, Ch 5, 5 Fatigue design*.

6.3.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with *Pt 4, Ch 5, 5 Fatigue design*.

6.3.6 Fatigue calculations for installations based on tanker conversions should take into account the fatigue damage accumulated as a trading tanker prior to conversion.

6.3.7 The design corrosion additions are to be deducted from the scantlings, measured at the time of conversion, as described in the LR ShipRight Procedure for Ship Units. This is to ensure the calculation of fatigue damage after conversion accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the converted hull structure is compatible with the required service life on location, *see also Pt 10, Ch 1, 6.3 Fatigue analysis 6.3.8*.

6.3.8 The minimum design fatigue life (after accounting for fatigue damage accumulated as a trading tanker prior to conversion) for structural elements should not be less than the intended field life, but should not be less than 5 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also Pt 4, Ch 5, 5 Fatigue design*.

6.3.9 The in-service Class survey reports for the vessel from build until conversion are to be submitted to LR for review. All critical locations in the existing structure which may be prone to fatigue cracking are to be examined by MPI or other suitable NDE methods at the time of conversion. The critical locations are to be selected based on the previous service history of the vessel and the recommendations in the LR ShipRight Procedure for Ship Units. A detailed NDE plan is to be submitted for approval.

6.4 Strength analysis

6.4.1 Requirements for direct calculations are given in the LR ShipRight Procedure for Ship Units.

■ *Section 7* Redeployment of existing units

7.1 General

7.1.1 If the 100-year environmental loads are larger than those of the previous geographical location then the requirements of *Pt 10, Ch 1, 6 Structural design – Tanker conversions* are to be applied for the redeployment of existing ship units.

7.2 Fatigue analysis

7.2.1 Fatigue calculations should take into account the fatigue damage accumulated prior to redeployment.

7.2.2 The design corrosion additions are to be deducted from the scantlings measured at the time of redeployment, as described in the LR ShipRight Procedure for Ship Units. This is to ensure the calculation of fatigue damage after redeployment accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the hull structure is compatible with the required service life on location, *see also Pt 10, Ch 1, 6.3 Fatigue analysis 6.3.8*.

■ *Section 8* Structural idealisation

8.1 General

8.1.1 General structural idealisation is covered in *Pt 4, Ch 3, 3 Structural idealisation*. Additional approaches relevant to *Pt 10 SHIP UNITS* are given in this Section.

8.2 Mixed steel grades

8.2.1 When a stiffener is of a higher strength material than the attached plate, the yield stress used for the calculation of the section modulus requirements in *Pt 10, Ch 3 Scantling Requirements* is, in general, not to be greater than 1,35 times the minimum specified yield stress of the attached plate. If the yield stress of the stiffener exceeds this limitation, the following criterion is to be satisfied:

$$\sigma_{\mathrm{yd-stf}} \leq \left(\sigma_{\mathrm{yd-plt}} - \left|\sigma_{\mathrm{hg}}\right|\right)\frac{Z_{\mathrm{net-plt}}}{Z_{\mathrm{net}}} + \left|\sigma_{\mathrm{hg}}\right| \ \mathrm{N/mm^2}$$

where

$\sigma_{\mathrm{yd-stf}}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{\mathrm{yd-plt}}$ = specified minimum yield stress of the material of the attached plate, in N/mm^2

σ_{hg} = maximum hull girder stress of sagging and hogging, in N/mm^2, as defined in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* and *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1* in *Pt 10, Ch 3 Scantling Requirements*, for stiffeners in cargo tank region and machinery spaces respectively and not to be taken as less than $0,4\,\sigma_{\mathrm{yd-plt}}$

Z_{net} = net section modulus, in way of face-plate/free edge of the stiffener, in cm^3

$Z_{\mathrm{net-plt}}$ = net section modulus, in way of the attached plate of stiffener, in cm^3

8.3 Effective bending span of local support members

8.3.1 The effective bending span, l_{bdg}, of a stiffener is defined for typical arrangements in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.3* to *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.7*. Where arrangements differ from those shown in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9* through *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8*, span definition may be specially considered.

8.3.2 The effective bending span may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective bending span is to be taken as the full length of the stiffener between primary member supports.

8.3.3 If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between primary member supports unless a backing bracket is fitted, *see Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9*.

8.3.4 The effective bending span may only be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted to the attached plating on the side opposite to that of the stiffener are not to be considered as effective in reducing the effective bending span.

8.3.5 The effective bending span, l_{bdg}, for stiffeners forming part of a double skin arrangement is to be taken as shown in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9*.

8.3.6 The effective bending span, l_{bdg}, for stiffeners forming part of a single skin arrangement is to be taken as shown in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9*.

8.3.7 For stiffeners supported by a bracket on one side of primary support members, the effective bending span is to be taken as the full distance between primary support members as shown in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9* (a). If brackets are fitted on both sides of the primary support member, the effective bending span is to be taken as in *Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9* (b), (c) and (d).

8.3.8 Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, *see Pt 10, Ch 1, 8.3 Effective bending span of local support members 8.3.9*.

8.3.9 For the calculation of the span point, the bracket length is not to be taken greater than 1,5 times the length of the arm on the bulkhead or base.

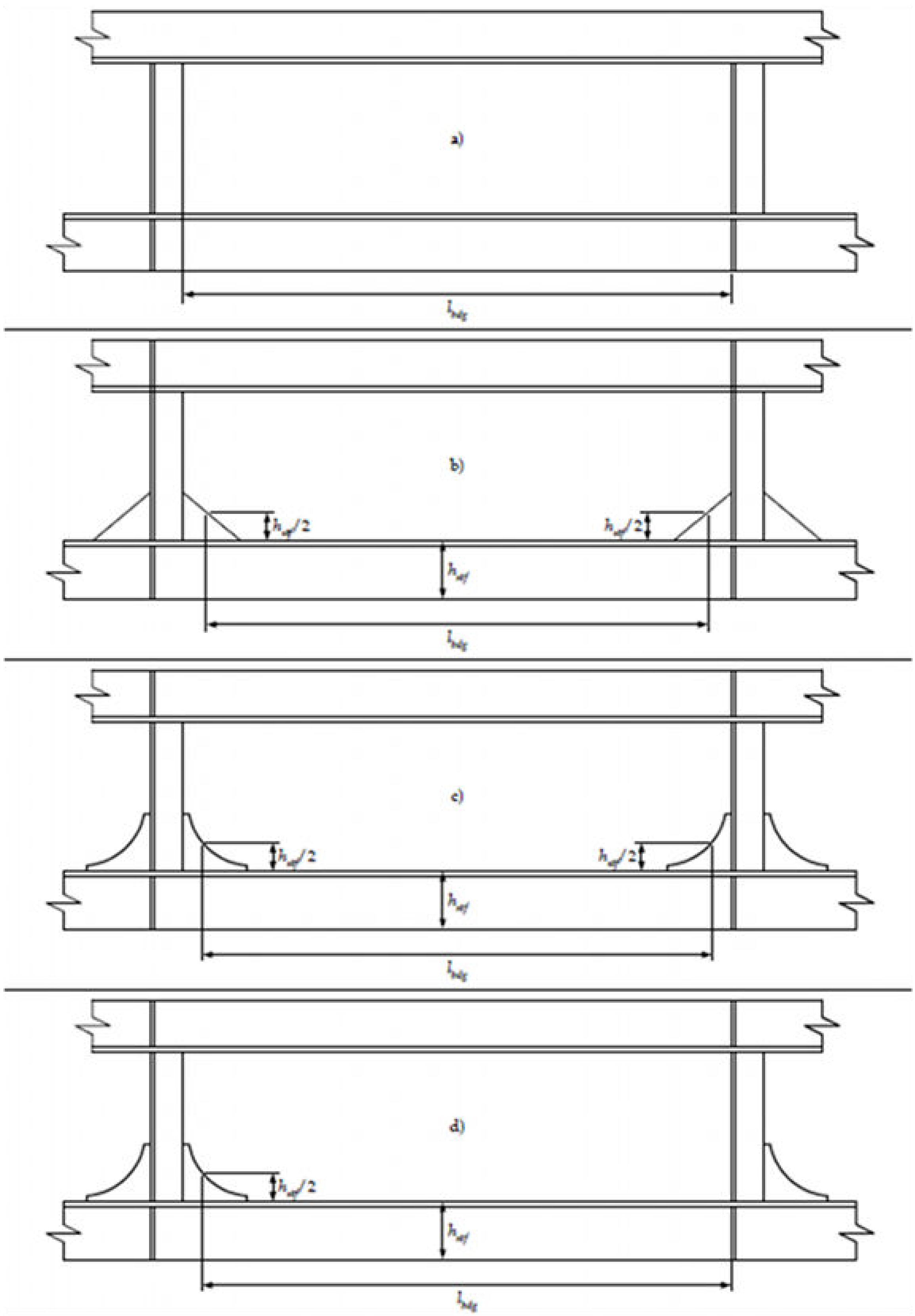


Figure 1.8.1 Effective Bending Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

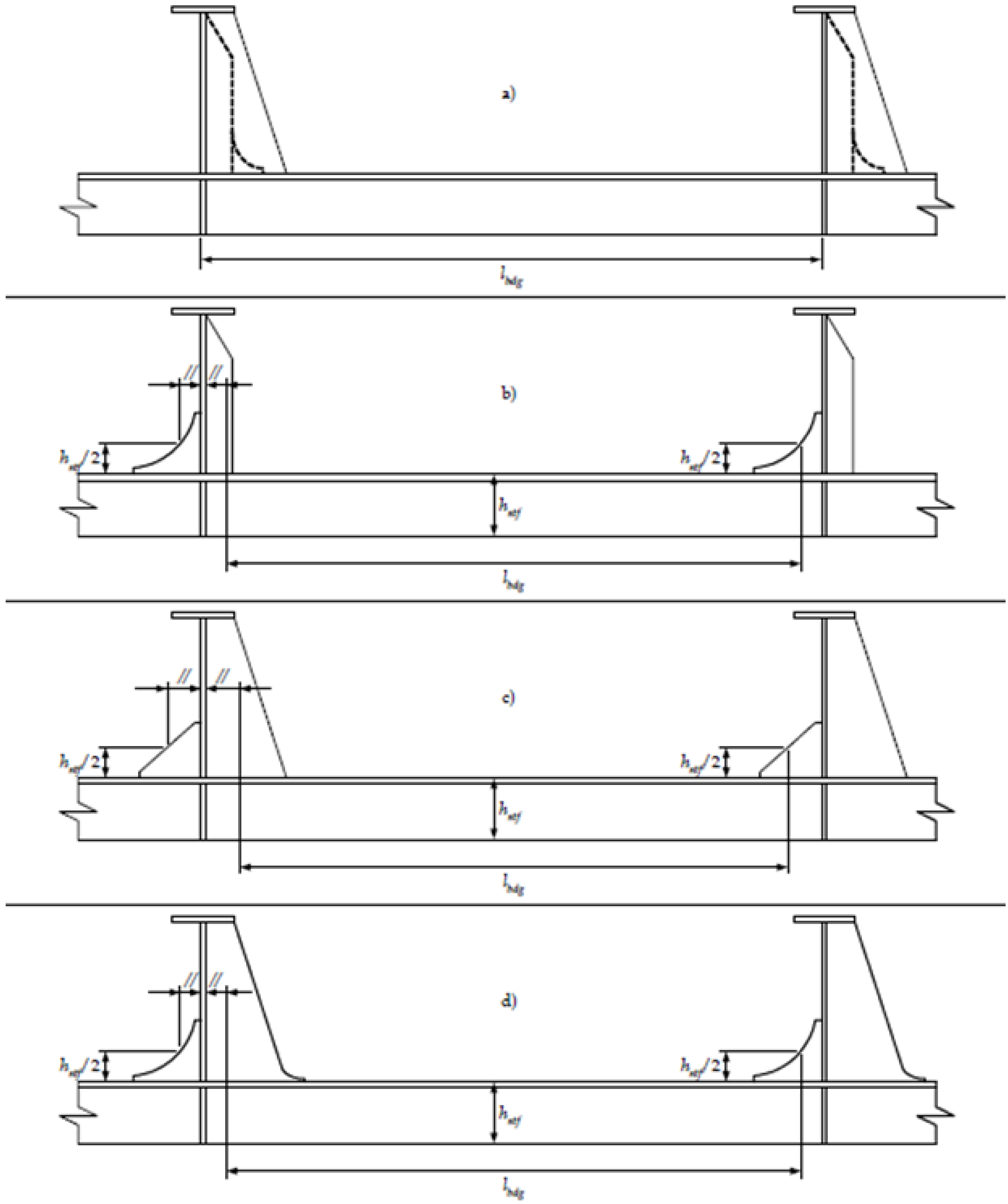


Figure 1.8.2 Effective Bending Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)

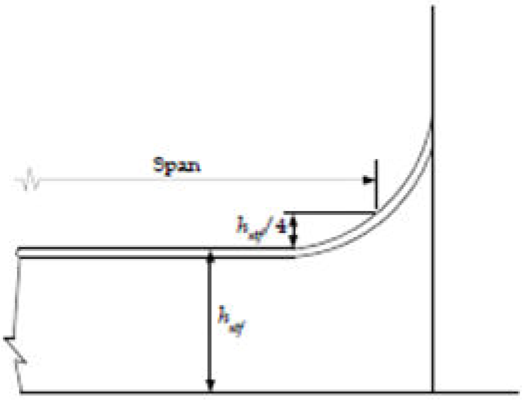


Figure 1.8.3 Effective Bending Span for Local Support Members with Continuous Face Plate along Bracket Edge

8.4 Effective shear span of local support members

8.4.1 The effective shear span, l_{shr}, of a stiffener is defined for typical arrangements in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.5* to *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.7* Effective shear span for other arrangements will be specially considered.

8.4.2 The effective shear span may be reduced due to the presence of brackets provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length as given in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.4*.

8.4.3 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener the effective shear span may be calculated using the longer effective bracket arm.

8.4.4 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span, l_{shr}, is not to be taken greater than:

$$l_{\text{shr}} \leq l - \frac{s}{2000} \quad \text{m}$$

Where:

l = full length of the stiffener between primary support members, in m

s = stiffener spacing, in mm

8.4.5 The effective shear span, l_{shr}, for stiffeners forming part of a double skin arrangement is to be taken as shown in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8*.

8.4.6 The effective shear span, l_{shr}, for stiffeners forming part of a single skin arrangement is to be taken as shown in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8*.

8.4.7 Where the face plate of the stiffener is continuous along the curved edge of the bracket, the effective shear span is to be taken as shown in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8*.

8.4.8 For curved and/or long brackets (length/height ratio) the effective bracket length is to be taken as the maximum inscribed 1:1.5 bracket as shown in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8* (c) and *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.8* (c).

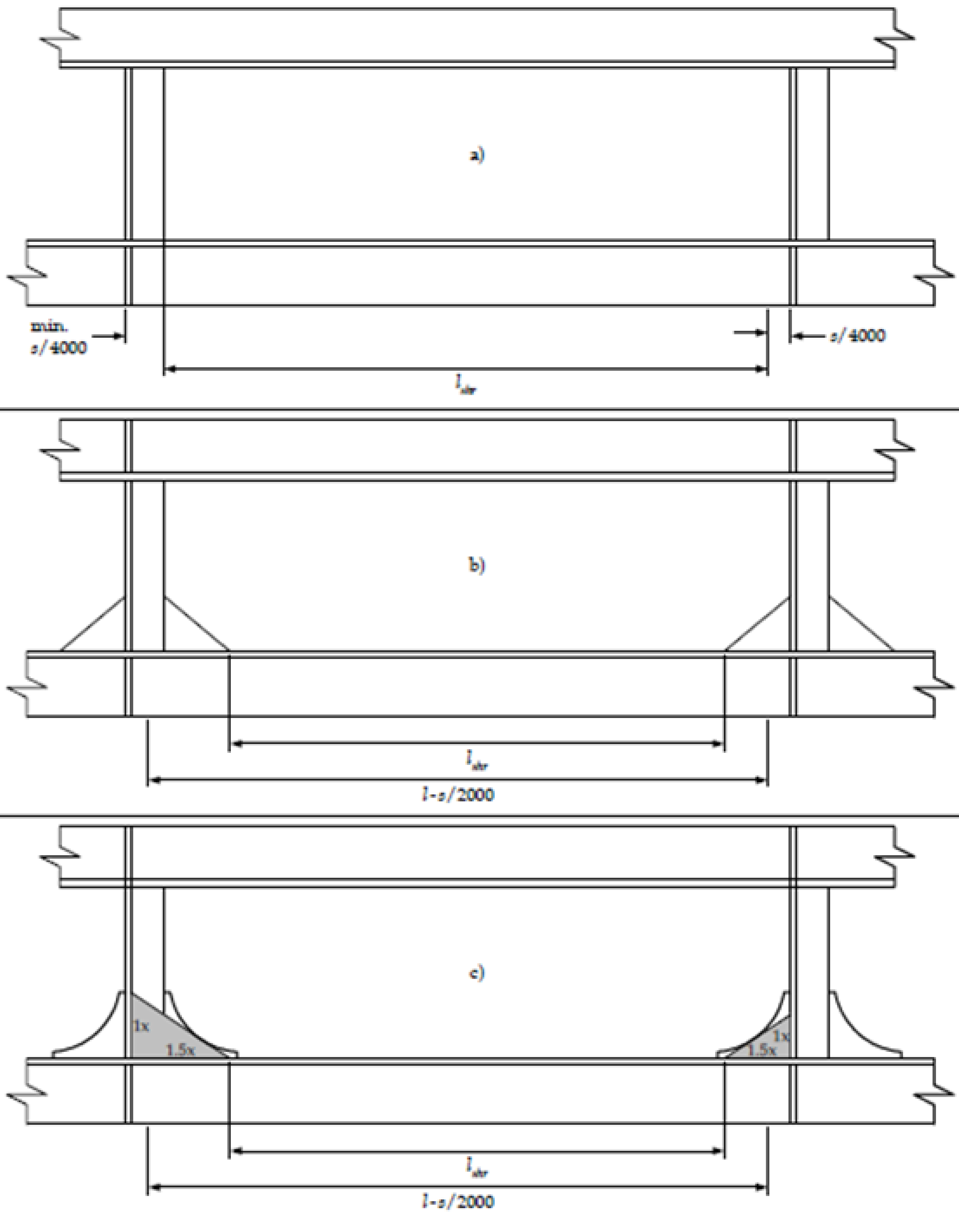


Figure 1.8.4 Effective Shear Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

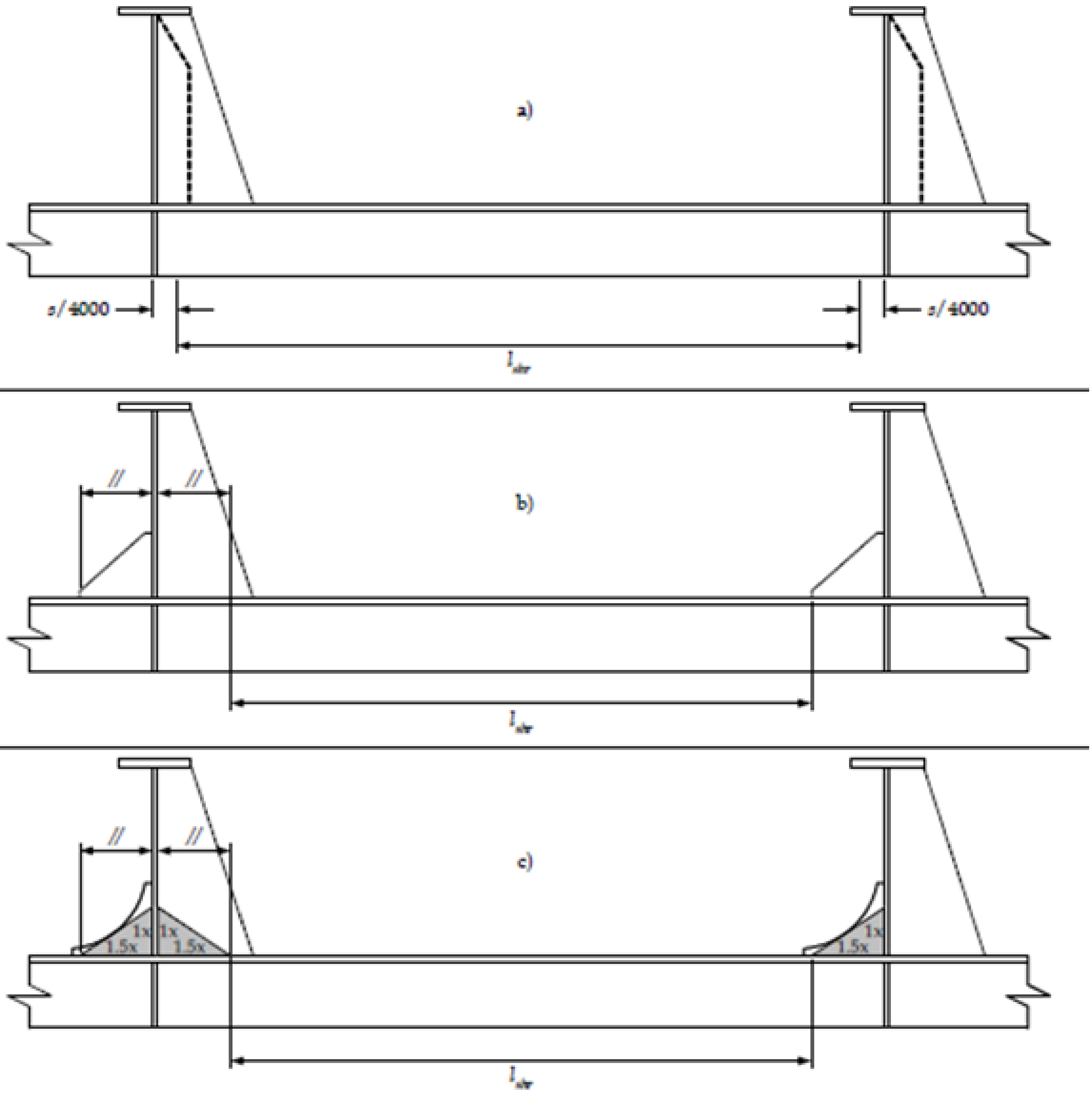


Figure 1.8.5 Effective Shear Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)

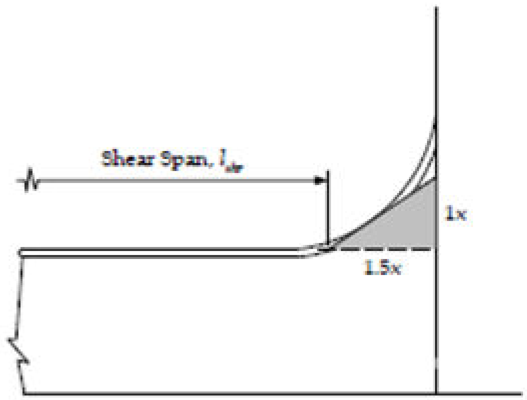


Figure 1.8.6 Effective Shear Span for Local Support Members with Continuous Face Plate along Bracket Edge

8.5 Effective shear span

8.5.1 The effective shear span of a stiffener may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length, as given in *Pt 10, Ch 1, 8.5 Effective shear span 8.5.3*.

8.5.2 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener, the effective shear span may be calculated using the longer effective bracket arm.

8.5.3 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span is not to be taken greater than:

$$l_{\text{shr}} \leq l - \frac{s}{2000} \text{ m}$$

where

l = full length of the stiffener between primary support members, in metres

s = stiffener spacing, in mm.

8.6 Effective elastic sectional properties of local support members

8.6.1 The net elastic shear area of local support members is to be taken as:

$$A_{\text{shr}-\text{el}-\text{net}} = \frac{\left(h_{\text{stf}} + t_{\text{p}-\text{net}}\right) t_{\text{w}-\text{net}} \sin \varphi_{\text{w}}}{100} \text{ cm}^2$$

where

h_{stf} = stiffener height, including face-plate, in mm

$t_{\text{p}-\text{net}}$ = net thickness of attached plate, in mm

$t_{\text{w}-\text{net}}$ = net web thickness, in mm

φ_{w} = angle between the stiffener web and attached plating, in degrees. φ_{w} is to be taken as 90° if the angle is greater than or equal to 75°.

8.6.2 effective shear depth of stiffeners is to be taken as:

$d_{\text{shr}} = \left(h_{\text{stf}} + t_{\text{p}-\text{net}}\right) \sin\ \varphi_{\text{w}}$ mm

where

$h_{\text{stf}}, t_{\text{p}-\text{net}}, \varphi_{\text{w}}$ are defined in *Pt 10, Ch 1, 8.6 Effective elastic sectional properties of local support members 8.6.1*.

8.6.3 The elastic net section modulus of local support members is to be taken as:

$Z_{\text{el}-\varphi-\text{net}} = Z_{\text{stf}-\text{net}} \sin\varphi_{\text{w}}$ cm^3

where

$Z_{el-\phi-net}$ = net section modulus of corresponding upright stiffener, i.e. when ϕ_w is equal to 90°, in cm^3

ϕ_w is defined in *Pt 10, Ch 1, 8.6 Effective elastic sectional properties of local support members 8.6.1*.

8.7 Effective plastic section modulus and shear area of stiffeners

8.7.1 The net plastic shear area of local support members is to be taken as:

$$A_{\text{shr}-\text{pl}-\text{net}} = \frac{\left(h_{\text{stf}} + t_{\text{p}-\text{net}}\right) t_{\text{w}-\text{net}} \sin\varphi_{\text{w}}}{100} \text{cm}^2$$

where

h_{stf} , t_{p-net} , ϕ_w are defined in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.1*

t_{w-net} = net web thickness, in mm.

8.7.2 The effective net plastic section modulus of local support members is to be taken as:

$$Z_{\text{pl}-\text{net}} = \frac{f_{\text{w}} d^2_{\text{w}} t_{\text{w}-\text{net}} \sin\varphi_{\text{w}}}{200} + \frac{\left(2_{\gamma} - 1\right) A_{\text{f}-\text{net}} \left(h_{\text{f}-\text{ctr}} \sin\varphi_{\text{w}} - \text{b}_{\text{f}-\text{ctr}} \cos\varphi_{\text{w}}\right)}{1000} \text{cm}^3$$

where

f_w = web shear stress factor

= 0,75 for flanged profile cross-sections with n = 1 or 2

= 1,0 for flanged profile cross-sections with n = 0 and for flat bar stiffeners

n = number of moment effective end supports of each member

= 0, 1 or 2

A moment effective end support may be considered where:

(a) the stiffener is continuous at the support;
(b) the stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners;
(c) the stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another stiffener (not a buckling stiffener).

d_{w} = depth of stiffener web, in mm:

= $h_{\text{stf}-\text{tf}-\text{net}}$ for T, L (rolled and built-up) and L2 profiles

= h_{stf} for flat bar and L3 profiles to be taken as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* for bulb profiles

= h_{stf} for flat bar and L3 profiles to be taken as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* for bulb profiles

γ = 0,25 (1 + $\sqrt{3 + 12\,\beta}$)

$\boldsymbol{\beta}$ = 0,5 for all cases, except L profiles without a mid span tripping bracket

= $\dfrac{10^6 t_{\text{w}-\text{net}}{}^2 f_{\text{b}} l^2{}_{\text{f}}}{80 b^2{}_{\text{f}} t_{\text{f}-\text{net}} h_{\text{f}-\text{ctr}}} + \dfrac{t_{\text{w}-\text{net}}}{2 b_{\text{f}}}$

but not to be taken greater than 0,5 for L (rolled and built-up) profiles without a mid span tripping bracket

$A_{\text{f}-\text{net}}$ = net cross-sectional area of flange, in mm^2

= $b_{\text{f}}\, t_{\text{f}-\text{net}}$ in general

= 0 for flat bar stiffeners

b_{f} = breadth of flange, in mm. For bulb profiles, *see Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2*

$b_{\text{f}-\text{ctr}}$ = distance from mid thickness of stiffener web to the centre of the flange area:

= 0,5 ($b_{\text{f}} - t_{\text{w}-\text{grs}}$) for rolled angle profiles

= 0 for T profiles

as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* for bulb profiles

$h_{\text{f}-\text{ctr}}$ = height of stiffener measured to the mid thickness of the flange:

= $h_{\text{stf}} - 0,5_{\text{f}-\text{net}}$ for profiles with flange of rectangular shape except for L3 profiles

= $h_{\text{stf}} - d_{\text{edge}} - 0.5 t_{\text{f}-\text{net}}$ for L3 profiles as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* for bulb profiles

d_{edge} = distance from upper edge of web to the top of the flange, in mm

f_{b} = 1,0 in general

= 0,8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member

= 0,7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support

l_{f} = length of stiffener flange between supporting webs, in metres, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted

$t_{\text{f}-\text{net}}$ = net flange thickness, in mm

= 0 for flat bar stiffeners as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* and *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2* for bulb profiles

t_{w-net}, h_{stf}, φ_w are defined in *Pt 10, Ch 1, 8.4 Effective shear span of local support members 8.4.1*.

Table 1.8.1 Characteristic flange data for HP bulb profiles

h_{stf} (mm)	d_w (mm)	b_{f-grs} (mm)	t_{f-grs} (mm)	b_{f-ctr} (mm)	h_{f-ctr} (mm)
200	171	40	14,4	10,9	188
220	188	44	16,2	12,1	206
240	205	49	17,7	13,3	225
260	221	53	19,5	14,5	244
280	238	57	21,3	15,8	263
300	255	62	22,8	16,9	281
320	271	65	25,0	18,1	300
340	288	70	26,4	19,3	318
370	313	77	28,8	21,1	346
400	338	83	31,5	22,0	374
430	363	90	33,9	24,7	402

NOTE

Characteristic flange data converted to net scantlings are given as:

$b_f = b_{f-grs*} + 2t_{w-net}$

$t_{f-net} = t_{f-grs*} - t_c$

$t_{w-net} = t_{wgrs} - t_c$

see Fig. 1.8.1

Table 1.8.2 Characteristic flange data for JIS bulb profiles

h_{stf} (mm)	d_w (mm)	b_{f-grs*} (mm)	t_{f-grs*} (mm)	b_{f-ctr} (mm)	h_{f-ctr} (mm)
180	156	34	11,9	9,0	170
200	172	39	13,7	10,4	188
230	198	45	15,2	11,7	217
250	215	49	17,1	12,9	235

NOTE

Characteristic flange data converted to net scantlings are as given in *Pt 10, Ch 1, 8.7 Effective plastic section modulus and shear area of stiffeners 8.7.2*

see Fig. 1.8.1

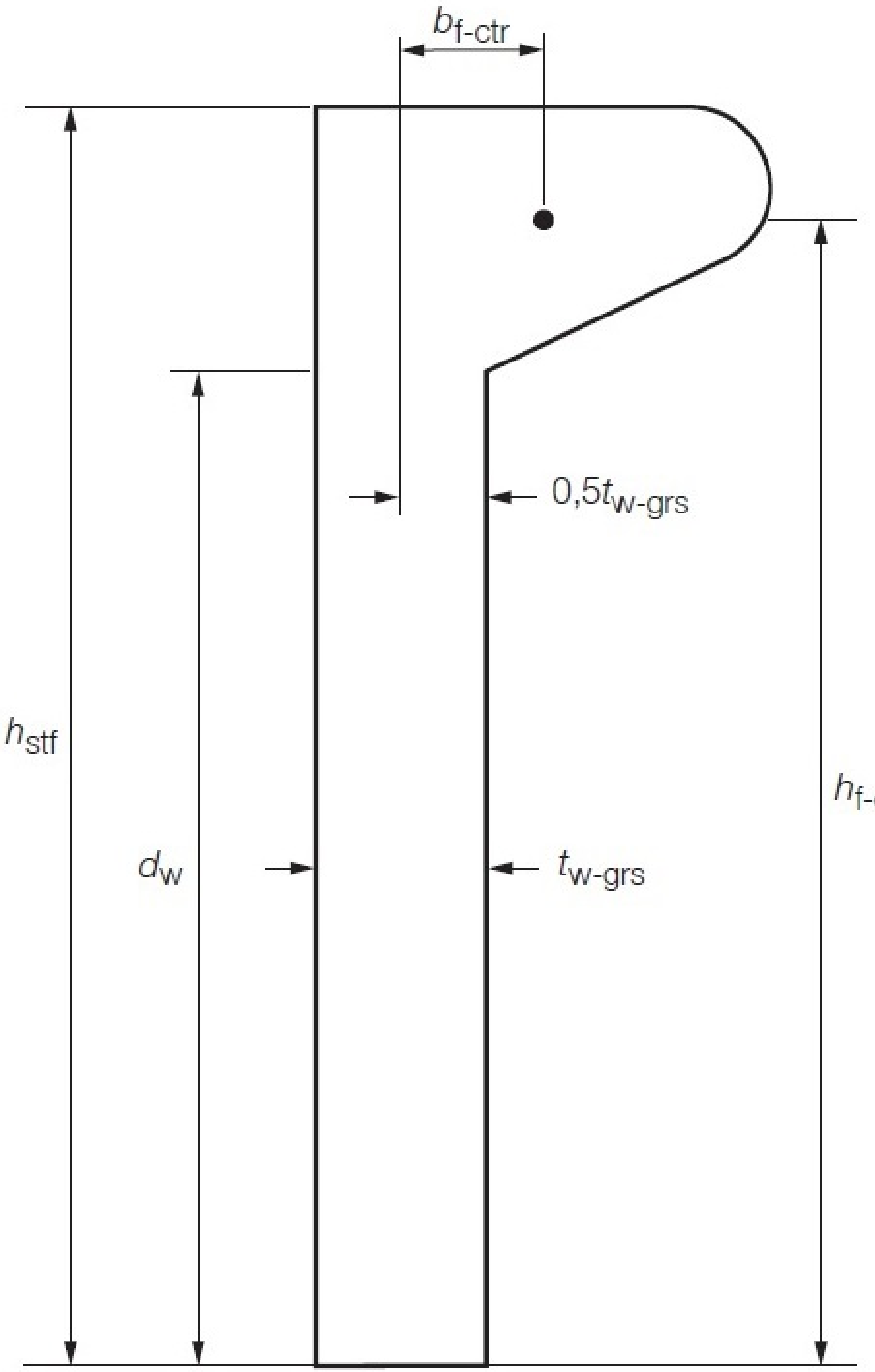


Figure 1.8.7 Characteristic data for bulb profiles

Section 9
Mooring structure

9.1 General

9.1.1 General requirements for turret mooring structures are given in*Pt 3, Ch 13, 3 Turret structures*

9.1.2 General requirements for mooring arm structures are given in *Pt 3, Ch 13, 4 Mooring arms and towers*.

9.1.3 The minimum hull modulus in way of turret areas and other large openings is to satisfy the Rule requirements for longitudinal strength. When the turret is situated within 0,5*L* amidships, the minimum hull midship section modulus about the transverse neutral axis at deck or keel is to be maintained in way of the turret opening. Increases in plate thicknesses are to take place gradually. Any reduction in hull section modulus should be kept to a minimum and compensation fitted where necessary.

9.1.4 For a turret-moored unit with a turret well opening, suitable precautions are to be taken to prevent damage to the well structure in transit and when disconnected, when applicable.

9.1.5 The hull structure in way of mooring connections is to be verified by direct calculation. In all cases, the structural analysis is to include a representative portion of the hull and tank structure, together with the integration of the mooring system with the unit's structure. The analysis is to be in accordance with the LR ShipRight Procedure for Ship Units and *Pt 4, Ch 5 Primary Hull Strength*, as applicable.

9.1.6 Continuity of primary structural elements is to be maintained as far as practicable in way of turret openings and mooring support structure.

9.1.7 Turret bearings are to comply with *Pt 3, Ch 2 Drilling Units*. The turret bearing support structure is to be integrated into the hull structure.

Section 10
Topside structure

10.1 General

10.1.1 The minimum scantlings of superstructures and deck-houses are to comply with the requirements of *Pt 3, Ch 8 Process Plant Facility* of the Rules for Ships. Bulwarks and guard-rails are to comply with *Pt 4, Ch 6, 10 Bulwarks and other means for the protection of crew and other personnel* but special consideration is to be given to the scantlings of bulwarks at the fore end or screens protecting the swivel stack. In general, the scantlings of bulwarks at the fore end are not to be less than required for deck-house fronts at the position under consideration.

10.1.2 For units with unconventional forward ends and units which may be subjected to high deck loading in excess of the minimum Rule heads due to loading from green seas, adequate protection by means of bulwarks and breakwater structure is to be provided at the forward end and the scantlings of the structure and its under-deck supports are to be specially considered. Where necessary the loadings are to be determined by model tests.

10.1.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading in accordance with *Pt 7, Ch 3 Fire Safety* are to be designed in accordance with *Pt 4, Ch 3, 4 Structural design loads* and permissible stress levels are to be in accordance with *Table 5.2.1 Factors of safety for the combined load cases* – load case (d) in *Pt 4, Ch 5, 2 Permissible stresses*

10.1.4 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures, including derricks and flare structures, are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with *Pt 3, Ch 8, 2 Structure*. Loading from the topsides should consider the most onerous scenarios, including environmental loads, equipment operating weights and inertia loads due to hull motions. Permissible stress levels are to comply with *Pt 4, Ch 5 Primary Hull Strength* or *Pt 4, Ch 3 Structural Design*.

10.1.5 Equipment supports are to take into account hull deflections when considered necessary.

■ Section 11
Green water and wave impact

11.1 General

11.1.1 Green water is taken to mean the overtopping by water in severe wave conditions, resulting in loading on the deck structure and any exposed equipment. Significant amounts of green water will have an impact on the vessel deck structural design, accommodation superstructure, equipment design and layout and may induce vibrations in the hull. The effects of green water loading should be accounted for, where applicable.

11.1.2 The requirements of *Pt 10, Ch 2, 3.8 Dynamic local loads*, Ch 2,7.4 and *Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads* are to be complied with, *see also* Section 5 and Section 6.

11.1.3 Appropriate measures should be considered to minimise green water effects on the structure and critical equipment, including bow shape design, flare, breakwaters and other protective structure such as turret housings. Adequate drainage arrangements must also be provided, *see also Pt 4, Ch 7, 10 Scuppers and sanitary discharges*.

11.1.4 Wave slamming effects should be taken into account for both hull and mooring structure design. Locations on the hull which may be subject to effects of wave impact include the forward bottom structure, stern structure, bow flare and bow side. The effects of slamming on the structure should be considered in design, particularly with regard to enhancement of global hull girder bending moments and shear loadings induced, local strength aspects and limitations to ballast draft conditions.

11.1.5 It is recommended that provisions are made during model testing, for measurement of both green water loading and wave slamming pressures which can be used for local structural design.

■ Section 12
Corrosion additions

12.1 General

12.1.1 Corrosion additions are to be in accordance with *Pt 4, Ch 3, 7 Corrosion additions*.

■ Section 13
Steel renewal criteria

13.1 General

13.1.1 Steel renewal criteria are given *Pt 1, Ch 3, 1.10 Steel renewal criteria*

■ Section 14
Local strength and structural details

14.1 General

14.1.1 Design for local strength of walkways, decks loaded by wheeled vehicles, helicopter landing areas, guard rails, bulwarks and other means for the protection of crew and other personnel is to comply with the requirements of *Pt 4, Ch 6 Local Strength*.

14.1.2 Watertight and weathertight integrity and load lines are to comply with the requirements of *Pt 4, Ch 7*, as applicable.

14.1.3 Welding, NDE, connections, structural details and fabrication tolerances are to comply with the requirements of *Pt 4, Ch 8 Welding and Structural Details*, as applicable.

14.1.4 Anchoring and towing equipment are to comply with the requirements of *Pt 4, Ch 9 Anchoring and Towing Equipment*, as applicable.

14.1.5 Steering arrangements are to comply with the requirements of *Pt 4, Ch 10 Steering and Control Systems*, as applicable.

14.1.6 Requirements additional to these Rules may be imposed by the National Administration in the area of operation and/or the country of administration, as applicable.

■ *Section 15*
In-service assessment

15.1 General

15.1.1 Any damage, defect, etc. is to be reported to LR without delay, *see Pt 1, Ch 2, 1.7 Legislative verification*.

15.1.2 All repairs and other measures are to be agreed with LR, *see Pt 1, Ch 2, 3.4 Damages, repairs and alterations*.

15.1.3 Details of an acceptable procedure for the assessment of structural defects in service are outlined in the LR ShipRight Procedure for Ship Units.

■ *Section 16*
Sloshing

16.1 General

16.1.1 When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the LR ShipRight Procedure for Ship Units. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for cargo bulk storage tanks.

■ *Section 17*
Hull girder ultimate strength

17.1 General

17.1.1 The hull girder ultimate strength is to be assessed in accordance with the LR ShipRight Procedure for Ship Units.

■ *Section 18*
Buckling

18.1 General

18.1.1 **Symbols**. The symbols used in this Chapter are defined as follows:

η_{allow} = allowable buckling utilisation factor, as defined in *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*

σ_x, σ_y = actual compressive stresses for plates, in N/mm^2

σ_x = compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener

τ = actual shear stress, in N/mm^2

σ_{xcr}, σ_{ycr} = critical compressive stress, in N/mm^2, as defined in *Pt 10, Ch 1, 18.2 Buckling of plates 18.2.1*

τ_{cr} = critical shear stress, in N/mm^2, as defined in *Pt 10, Ch 1, 18.2 Buckling of plates 18.2.1*

K = buckling factor, *see Pt 10, Ch 1, 18.1 General 18.1.2*

σ_E = reference stress, in N/mm^2

= $0{,}9E\left(\dfrac{t_{net}}{l_a}\right)^2$

E = modulus of elasticity, 206 000 N/mm^2

t_{net} = net thickness of plate panel, in mm

l_a = length of the side of the plate panel, as defined in *Pt 10, Ch 1, 18.1 General 18.1.2*, in mm

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

C_x, C_y, C_τ = reduction factors, as given in Table 1.18.1

σ_b = bending stress at the midspan of the stiffener according to *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2*, in N/mm^2

s = stiffener spacing, in mm

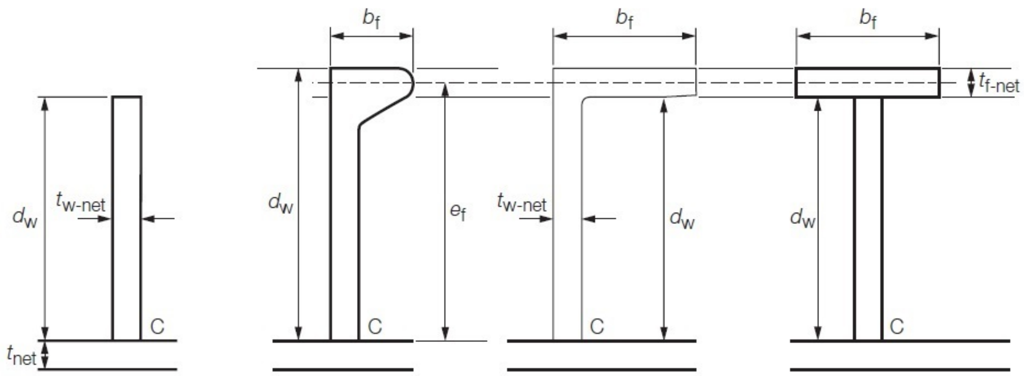
d_w = depth of web plate, in mm, as shown in *Pt 10, Ch 1, 18.1 General 18.1.1*

t_{f-net} = net flange thickness, in mm

t_{w-net} = net web thickness, in mm

b_f = flange breadth, in mm

ν = Poisson's ratio, 0,3.



NOTE
Measurements of breadth and depth are based on gross scantlings

Figure 1.18.1 Stiffener cross-sections

18.1.2 **Scope**

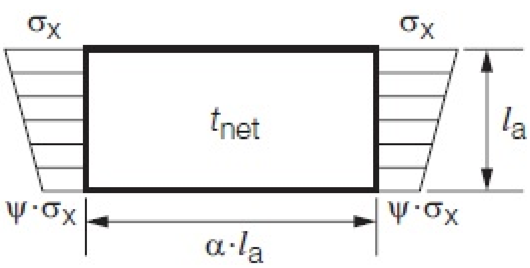
(a) This Section contains the methods for determination of the buckling capacity, definitions of buckling utilisation factors and other measures necessary to control buckling of plate panels, stiffeners and primary support members.

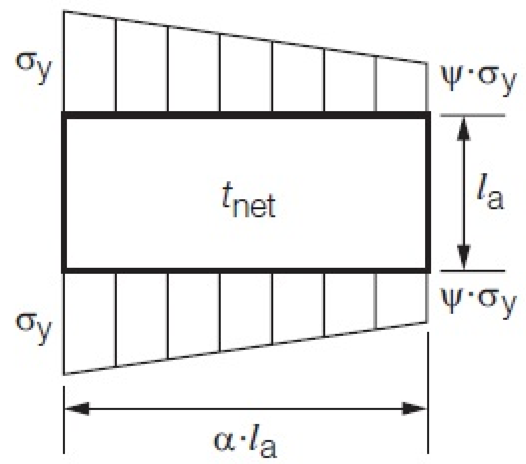
(b) The buckling utilisation factor is to satisfy the following criteria:

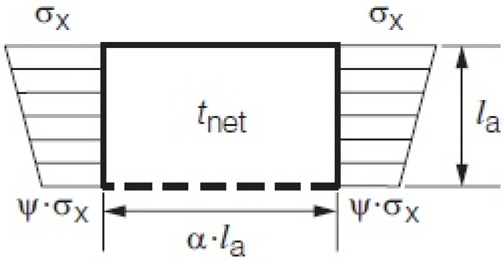
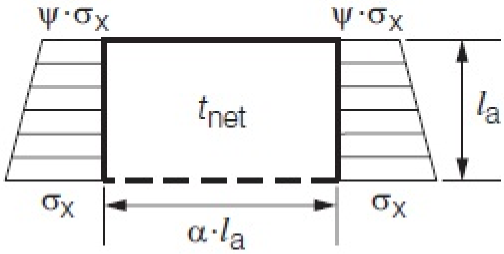
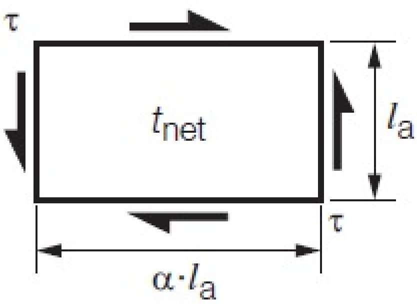
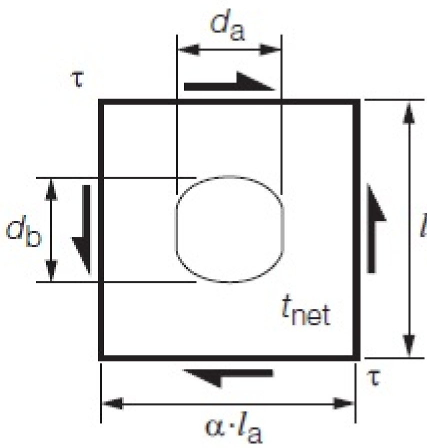
$$\eta \leq \eta_{\text{allow}}$$

(c) For structural idealisation and definitions see also *Pt 10, Ch 1, 8 Structural idealisation*. The thickness and section properties of plates and stiffeners are to be taken as specified by the appropriate Rule requirements.

Table 1.18.1 Buckling factor and reduction factor for plane plate panels

Case	Stress ratio ψ	Aspect ratio α	Buckling factor *K*	Reduction factor *C*
1 	$1 \geq \psi \geq 0$	α > 1	$K = \dfrac{8,4}{\psi + 1,1}$	$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
	$0 > \psi > -1$		$K = 7,63 - \psi\,(6,26 - 10\psi)$	where
	$\psi \leq -1$		$K = 5,975\,(1 - \psi)^2$	$c = (1,25 - 0,12\psi) \leq 1,25$ $\lambda_c = \left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$

2 	1 ≥ ψ ≥ 0	α > 1	$K = \left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{(\psi + 1,1)}$	$C_y = c\left(\frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2}\right)$ where
	0 > ψ > −1	1 ≤ α ≤ 1,5	$K = \left[1 + \frac{1}{\alpha^2}\right]^2 \frac{2,1(1 + \psi)}{1,1} - \frac{\psi}{\alpha^2}(13,9 - 10\psi)$	c =(1,25 − 0,12ψ) ≤ 1,25 R =λ (1 − λ/c) for λ < λ_c R = 0,22 for λ ≥ λ_c
		α > 1,5	$K = \left[1 + \frac{1}{\alpha^2}\right]^2 \frac{2,1(1 + \psi)}{1,1} - \frac{\psi}{\alpha^2}\left(5,87 - 1,87\alpha^2 + \frac{8,6}{\alpha^2} - 10\psi\right)$	λ_c =0,5c $(1 + \sqrt{1 - 0,88/c})$ $F = \left(1 - \left(\frac{K}{0,91} - 1\right)/\lambda_p^2\right)c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0,5$ and $1 \leq \lambda_p^2 \leq 3$ c_1 =1 for σ_y due to direct loads (3)
	ψ ≤ −1	$1 \leq \alpha \leq \frac{3(1 - \psi)}{4}$	$K = \left(\frac{1 - \psi}{\alpha}\right)^2 5,975$	c_1 =(1 − 1/α) ≥ 0 for σ_y due to bending (in general) (2) c_1 =0 for σ due to bending in extreme load cases (e.g. w/ t.bhds.)
		$\alpha > \frac{3(1 - \psi)}{4}$	$K = \left(\frac{1 - \psi}{\alpha}\right)^2 3,9675 + 0,5375\left(\frac{1 - \psi}{\alpha}\right)^4 + 1,87$	$H = \lambda - \frac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \geq R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$

3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4\left(0,425 + 1/\alpha^2\right)}{3\psi + 1}$	$c_x = 1$ for $\lambda \leq 0,7$
	$0 > \psi \geq -1$		$K = 4\left(0,425 + 1/\alpha^2\right)\left(1 + \psi\right) - 5\psi\left(1 - 3,42\psi\right)$	$c_x = \dfrac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0,425 + \dfrac{1}{\alpha^2}\right)\dfrac{3 - \psi}{2}$	
5 			$K = K_\tau \sqrt{3}$	$c_\tau = 1$ for $\lambda \leq 0,84$
		$\alpha \geq 1$	$K_\tau = \left[5,34 + \dfrac{4}{\alpha^2}\right]$	$c_\tau = \dfrac{0,84}{\lambda}$ for $\lambda > 0,84$
		$0 < \alpha < 1$	$K_\tau = \left[4 + \dfrac{5,34}{\alpha^2}\right]$	
6 			$K = K' r$ K' = K according to Case 5 r = opening red. factor $r = \left(1 - \dfrac{d_a}{\alpha\, l_a}\right)\left(1 - \dfrac{d_b}{l_a}\right)$ $\dfrac{d_a}{\alpha\, l_a} \leq 0,7$ and $\dfrac{d_b}{l_a} \leq 0,7$	

where

ψ = the ratio between smallest and largest compressive stress, as shown for Cases 1 to 4

l_a = length, in mm, of the shorter side of the plate panel for Cases 1 and 2

l_a = length, in mm, of the side of the plate panel, as defined for Cases 3, 4, 5 and 6

α = aspect ratio of the plate panel
Edge boundary conditions: - - - - - - - - - plate edge free ——————————— plate edge simply supported
NOTES 1. Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates. 2. c_1 due to bending (in general) corresponds to straight edges (uniform displacement) of a plate panel integrated in a large structure. This value is to be applied for hull girder buckling and buckling of web plate of primary support members in way of openings. 3. c_1 for direct loads corresponds to a plate panel with edges not restrained from pull-in which may result in non-straight edges.

18.2 Buckling of plates

18.2.1 Uni-axial buckling of plates.

(a) The buckling utilisation factor for uni-axial stress is to be taken as:

$\eta = \frac{\sigma_x}{\sigma_{xcr}}$ for compressive stresses in x-direction

$\eta = \frac{\sigma_y}{\sigma_{ycr}}$ for compressive stresses in y-direction

$\eta = \frac{\tau}{\tau_{cr}}$ for shear stress.

(b) Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{K\sigma_E}}$$

(c) The critical stresses, σ_{xcr}, σ_{ycr} or τ_{cr} , of plate panels subject to compression or shear, respectively, is to be taken as:

$$\sigma_{xcr} = C_x \sigma_{yd}$$

$$\sigma_{ycr} = C_y \sigma_{yd}$$

$$\tau_{cr} = C_\tau \frac{\sigma_{yd}}{\sqrt{3}}$$

18.3 Buckling of stiffeners

18.3.1 Critical compressive stress.

(a) The buckling utilisation factor of stiffeners is to be taken as the maximum of the column and torsional buckling mode as given in *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2* and *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.3*

18.3.2 Column buckling mode.

(a) Stiffeners are to be verified against the column buckling mode as given in *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2* with the allowable buckling utilisation factor, η_{allow} , *see Pt 10, Ch 1, 18.1 General 18.1.2*. Stiffeners not subjected to lateral pressure and that have a net moment of inertia, I_{net} , complying with *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2* have acceptable column buckling strength and need not be verified against *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2*.

(b) The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

where

σ_b = bending stress at the midspan of the stiffener according to *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2*, in N/mm^2.

(c) The bending stress in the stiffener is equal to:

$$\sigma_b = \frac{M_o + M_1}{1000 Z_{net}} \text{ N/mm}^2$$

where

Z_{net} = net section modulus of stiffener, in cm^3, including effective breadth of plating according to *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.4*

(i) if lateral pressure is applied to the stiffener:

Z_{net} = the section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener

Z_{net} = the section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener

(ii) if no lateral pressure is applied on the stiffener:

Z_{net} = the minimum section modulus among those calculated at flange and attached plate

M_1 = bending moment, in Nmm, due to the lateral load *P*

= $\dfrac{P\, s\, l_{stf}^{\;2}}{24} 10^3$

P = lateral load, in kN/m^2

l_{stf} = span of stiffener, in metres, equal to spacing between primary support members

M_o = bending moment, in Nmm, due to the lateral deformation *w* of stiffener

= $F_E \left(\dfrac{P_z w}{c_f - P_z} \right)$ where $\left(c_f - P_z \right) > 0$

F_E = ideal elastic buckling force of the stiffener, in N

= $\left(\dfrac{\pi^2}{l_{stf}^{\;2}} \right) E\, I_{net}\ 10^{-2}$

I_{net} = moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.4*. I_{net} is to comply with the following requirement:

= $I_{net} \geq \dfrac{s\, t_{net}^{\;3}}{12} 10^{-4}$

t_{net} = net thickness of plate flange, to be taken as the mean thickness of the two attached plate panels, in mm

P_z = nominal lateral load, in N/mm^2, acting on the stiffener due to membrane stresses, σ_x, σ_y and τ_1, in the attached plate in way of the stiffener midspan:

$$= \frac{t_{net}}{s}\left(\sigma_{xl}\left(\frac{\pi s}{1000 l_{stf}}\right)^2 + 2c_y\,\sigma_y + \sqrt{2}\,\tau_1\right)$$

σ_{xl} = $\sigma_x\left(1+\frac{A_{net}}{s\,t_{net}}\right)$ N/mm^2

τ_1 = $\left[\tau - t_{net}\sqrt{\sigma_{yd}E\left(\frac{m_1}{(1000 l_{stf})2}+\frac{m_2}{s^2}\right)}\right] \geq 0$

with m_1 and m_2 taken equal to

m_1 = 1,47 m_2 = 0,49 for $\frac{1000 l_{stf}}{s} \geq 2{,}0$

m_2 = 1,96 m_2 = 0,37 for $\frac{1000 l_{stf}}{s} \geq 2{,}0$

A_{net} = net sectional area of the stiffener without attached plating, in mm^2

c_y = factor taking into account the membrane stresses in the attached plating acting perpendicular to the stiffener's axis

= 0,5 (1 + ψ) for 0 ≤ ψ ≤ 1

= $\frac{0{,}5}{1-\psi}$ for ψ < 0

ψ = edge stress ratio for Case 2 according to *Pt 10, Ch 1, 18.1 General 18.1.2*

σ_y = membrane compressive stress in the attached plating acting perpendicular to the stiffener's axis, in N/m^2

τ = shear membrane stress in the attached plating, in N/mm^2

w = deformation of stiffener, in mm

= $w_0 + w_1$

w_0 = assumed imperfection, in mm

= min $\left[\frac{1000 l_{stf}}{250}, \frac{s}{250}, 10\right]$

For stiffeners sniped at both ends is not to be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.4*

w_1 = deformation of stiffener at midpoint of stiffener span due to lateral load *P*, in mm. In case of uniformly distributed load w_1 is to be taken as:

= $\frac{P s\, l_{stf}^4}{384 \cdot E\, I_{net}} 10^5$

c_f = elastic support provided by the stiffener, in N/mm^2

$$= F_E \frac{\pi^2}{l_{stf}^2}\left(1 + c_p\right) 10^{-6}$$

$$c_p = \frac{1}{1 + \frac{0,91}{c_a}\left(\frac{12 I_{net} 10^4}{s\, t_{net}^3} - 1\right)}$$

$$c_a = \left[\frac{1000 l_{stf}}{2s} + \frac{2s}{1000 l_{stf}}\right]^2 \text{ for } l_{stf} \geq \frac{2s}{1000}$$

$$c_a = \left[1 + \left(\frac{1000 l_{stf}}{2s}\right)^2\right]^2 \text{ for } l_{stf} < \frac{2s}{1000}$$

(d) Stiffeners not subjected to lateral pressure are considered as complying with the requirements of *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2* if their net moments of inertia, in cm^4, satisfy the following requirement:

$$I_{net} \geq \frac{100 P_z l_{stf}^2}{\pi^2}\left[\frac{w_0\left(e_f - 0,5 t_{f-net}\right)}{\eta_{allow}\,\sigma_{yd} - \sigma_x} + \frac{l_{stf}^2}{E\pi^2} 10^6\right]$$

where

e_f = distance from connection to plate (*C* as shown in *Pt 10, Ch 1, 18.1 General 18.1.1*) to centre of flange, in mm

= $(d_w - 0,5 t_{f-net})$ for bulb flats

= $(d_w + 0,5 t_{f-net})$ for angles and T bars

NOTE

Other parameters are as defined in *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2*.

18.3.3 **Torsional buckling mode.**

(a) The torsional buckling mode is to be verified against the allowable buckling utilisation factor, η_{allow}, *see Pt 10, Ch 1, 18.1 General 18.1.2*. The buckling utilisation factor for torsional buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x}{C_T \sigma_{yd}}$$

where

σ_x = compressive axial stress in the stiffener, in N/mm^2, calculated at the attachment point of the stiffener to the plate, in way of the midspan of the stiffener measured along the global x-axis

C_T = torsional buckling coefficient

= 1,0 for $\lambda_T \leq 0,2$

= $\dfrac{1}{\varphi + \sqrt{\varphi^2 - \lambda_T^2}}$ for $\lambda_T > 0,2$

$\mathbf{\Phi}$ = 0,5 (1 + 0,21 (λ_T – 0,2) + λ_T^2)

λ_T = reference degree of slenderness for torsional buckling

= $\sqrt{\dfrac{\sigma_{yd}}{\sigma_{ET}}}$

σ_{ET} = reference stress for torsional buckling, in N/mm^2

= $\dfrac{E}{I_{p-net}}\left(\dfrac{\epsilon\,\pi^2 I_{w-net}10^{-4}}{l_t^2} + 0,385 I_{T-net}\right)$

I_{P-net} = net polar moment of inertia of the stiffener about point *C*, in cm^4, as shown in *Pt 10, Ch 1, 18.1 General 18.1.1* and *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.3*

I_{T-net} = net St.Venant's moment of inertia of the stiffener, in cm, as shown in *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.3*

I_{w-net} = net sectorial moment of inertia of the stiffener about point *C*, in cm^6, as shown in *Pt 10, Ch 1, 18.1 General 18.1.1* and *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.3*

ϵ = degree of fixation $1 + 1000\sqrt{\dfrac{l_t^4}{\frac{3}{4}\pi^4 I_{w-net}\left(\frac{s}{t_{net}^3} + \frac{4(e_f - 0,5t_{f-net})}{3t_{w-net}^3}\right)}}$

l_t = torsional buckling length to be taken equal the distance between tripping supports, in metres, distance from connection to plate (*C* in *Pt 10, Ch 1, 18.1 General 18.1.1*) to centre of flange, in mm

e_f = (d_w – 0,5 t_{f-net}) for bulb flats

= (d_w + 0,5 t_{f-net}) for angles and T Bars net web area, in mm^2

A_{w-net} = (e_f – 0,5 t_{f-net}) t_{w-net} net flange area, in mm^2

A_{f-net} = $b_f t_{f-net}$

Table 1.18.2 Moments of inertia

Section property	Flat bars	Bulb flats, angles and T bars
I_{P-net}	$\dfrac{d_w^3 t_{w-net}}{3\,x\,10^4}$	$\left(\dfrac{A_{w-net}(e_f - 0,5t_{f-net})^2}{3} + A_{f-net}e_f^2\right)10^{-4}$
I_{T-net}	$\dfrac{d_w t_{w-net}^3}{3\,x\,10^4}\left(1 - 0,63\dfrac{t_{w-net}}{d_\omega}\right)$	$\dfrac{(e_f - 0,5t_{f-net})\,t_{w-net}^3}{3\,x\,10^4}\left(1 - 0,63\dfrac{t_{w-net}}{e_f - 0,5t_{f-net}}\right) + \dfrac{b_f t_{f-net}^3}{3\,x\,10^4}\left(1 - 0,63\dfrac{t_{f-net}}{b_f}\right)$
$I_{\omega-net}$	$\dfrac{d_w^3 t_{w-net}^3}{36\,x\,10^6}$	for bulb flats and angles: $\dfrac{A_{f-net}e_f^2 b_f^2}{12\,x\,10^6}\left(\dfrac{A_{f-net} + 2,6A_{w-net}}{A_{f-net} + A_{w-net}}\right)$ for T bars: $\dfrac{b_f^3 t_{f-net}e_f^2}{12\,x\,10^6}$

18.3.4 **Effective breadth of attached plating.**

(a) The effective breadth of attached plating of ordinary stiffeners is to be taken as:

b_{eff} = min ($C_{\text{x}}\, s,\ c_{\text{s}}\, s$)

where

χ_{s} = $0{,}0035\left(\dfrac{1000 l_{\text{eff}}}{s}\right)^3 - 0{,}0673\left(\dfrac{1000 l_{\text{eff}}}{s}\right)^2 + 0{,}4422\left(\dfrac{1000 l_{\text{eff}}}{s}\right) - 0{,}0056 \leq 1{,}0$

C_{x} = average reduction factor for buckling of the two attached plate panels, according to Case 1 in *Pt 10, Ch 1, 18.1 General 18.1.2*

l_{stf} = span of stiffener, in metres, equal to spacing between primary support members

l_{eff} = effective span of stiffeners in metres

= l_{stf} if simply supported at both ends

= 0,6 l_{stf} if fixed at both ends.

18.4 Primary support members

18.4.1 **Buckling of web plate of primary support members in way of openings.**

(a) The web plate of primary support members with openings is to be assessed for buckling, based on the combined axial compressive and shear stresses. The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels, as shown in *Pt 10, Ch 1, 18.4 Primary support members 18.4.1*. The buckling utilisation factor, η, is to be taken as:

$$\eta = \left(\frac{|\sigma_{\text{av}}|}{C\,\sigma_{\text{yd}}}\right)^{\text{e}} + \left(\frac{|\tau_{\text{av}}|\sqrt{3}}{C_{\tau}\,\sigma_{\text{yd}}}\right)^{\text{e}_{\tau}}$$

where

σ_{av} = average compressive stress in the area of web plate being considered according to Case 1, 2 or 3 in *Pt 10, Ch 1, 18.1 General 18.1.2*, in N/mm^2

τ_{av} = average shear stress in the area of web plate being considered according to Case 5 or 6 in *Pt 10, Ch 1, 18.1 General 18.1.2*, in N/mm^2

e = 1 + C^4 exponent for compressive stress

e_τ = 1 + $C\, C^2_{\tau}$ exponent for shear stress

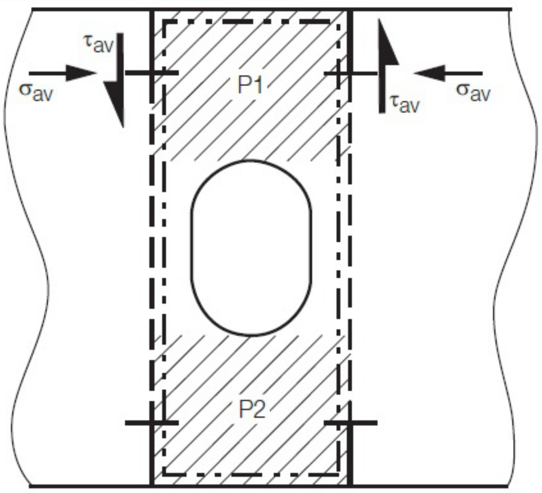
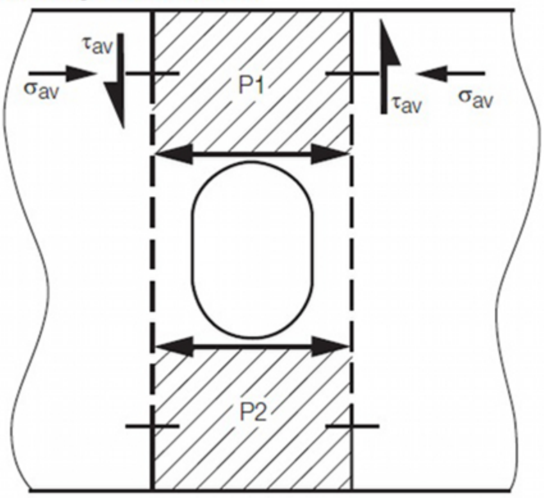
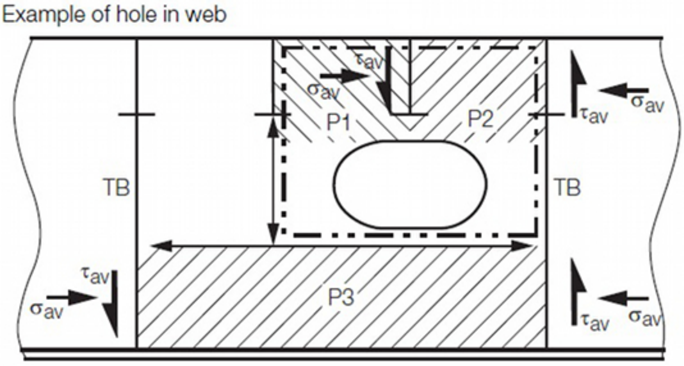
C = C_{x} reduction factor according to Case 1 or 3 in *Pt 10, Ch 1, 18.1 General 18.1.2*

C = C_{y} reduction factor according to Case 2 in *Pt 10, Ch 1, 18.1 General 18.1.2*

C_{τ} = reduction factor according to Case 5 or 6 in *Pt 10, Ch 1, 18.1 General 18.1.2*.

(b) The reduction factors, C_{x} or C_{y} in combination with C_{τ} , of the plate panel(s) of the web adjacent to the opening is to be taken as shown in *Pt 10, Ch 1, 18.1 General 18.1.2*.

Table 1.18.3 Reduction factors

<table>
<tr><th>Mode</th><th>C_x, C_y</th><th>C_τ</th></tr>
<tr><td>(a) Without edge reinforcements
</td><td>Separate reduction factors are to be applied to areas P1 and P2 using Case 3 in Pt 10, Ch 1, 18.1 General 18.1.2, with edge stress ratio:
ψ = 1,0</td><td>A common reduction factor is to be applied to areas P1 and P2 using Case 6 in Pt 10, Ch 1, 18.1 General 18.1.2 for area marked:
</td></tr>
<tr><td>(b) With edge reinforcements
</td><td>Separate reduction factors are to be applied for areas P1 and P2 using:
C_x for Case 1 or C_y , for Case 2, see Pt 10, Ch 1, 18.1 General 18.1.2
with stress ratio ψ = 1,0</td><td>Separate reduction factors are to be applied for areas P1 and P2 using Case 5 in Pt 10, Ch 1, 18.1 General 18.1.2</td></tr>
<tr><td>(c) Example of hole in web
</td><td colspan="2">Panels P1 and P2 are to be evaluated in accordance with (a).
Panel P3 is to be evaluated in accordance with (b)</td></tr>
<tr><td colspan="3">NOTE
Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.</td></tr>
</table>

18.5 Other structures

18.5.1 **Struts, pillars and cross ties.**

(a) The critical buckling stress for axially compressed struts, pillars and cross ties is to be taken as the lesser of the column and torsional critical buckling stresses. The buckling utilisation factor, η, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where

σ_{av} = average axial compressive stress in the member, in N/mm^2

σ_{cr} = minimum critical buckling stress according to *Pt 10, Ch 1, 18.5 Other structures 18.5.1*, in N/mm^2.

(b) The critical buckling stress in compression for each mode is to be taken as:

$$\sigma_{cr} = \sigma_e \text{ for } \sigma_E \le 0,5\,\sigma_{yd}$$

$$\sigma_{cr} = \left(1 - \frac{\sigma_{yd}}{4\,\sigma_E}\right)\sigma_{yd} \text{ for } \sigma_E > 0,5\,\sigma_{yd}$$

where

σ_E = elastic compressive buckling stress, in N/mm^2, given for each buckling mode, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1* to *Pt 10, Ch 1, 18.5 Other structures 18.5.1*.

(c) The elastic compressive column buckling stress of pillars subject to axial compression is to be taken as:

$$\sigma_E = 0,001 E f_{end} \frac{I_{net50}}{A_{pill-net50}\, l_{pill}^2} \text{ N/mm}^2$$

where

I_{net50} = net moment of inertia about the weakest axis of the cross-section, in cm^4

$A_{pill-net50}$ = net cross-sectional area of the pillar, in cm^2

f_{end} = end constraint factor:

1,0 where both ends are pinned

2,0 where one end is pinned and the other end is fixed

4,0 where both ends are fixed

A pillar end may be considered fixed when effective brackets are fitted. These brackets are to be supported by structural members with greater bending stiffness than the pillar

Column buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

l_{pill} = unsupported length of the pillar, in metres.

(d) The elastic torsional buckling stress, σ_{ET}, with respect to axial compression of pillars is to be taken as:

$$\sigma_{ET} = \frac{G I_{sv-net50}}{I_{pol-net50}} + \frac{0,001 f_{end} E\, c_{warp}}{I_{pol-net50}\, l_{pill}^2} \text{ N/mm}^2$$

where

G = shear modulus

$= \dfrac{E}{2(1+\nu)}$

$I_{sv-net50}$ = net St.Venant's moment of inertia, in cm^4, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

$I_{pol-net50}$ = net polar moment of inertia about the shear centre of cross-section

= $I_{y-net50} + I_{z-net50} + A_{net50}\,(y^2_0 + z^2_0)$ cm^4

f_{end} = end constraint factor:

1,0 where both ends are pinned
2,0 where one end is pinned and the other end is fixed
4,0 where both ends are fixed
Elastic torsional buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

c_{warp} = warping constant, in cm^6, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

l_{pill} = unsupported length of the pillar, in metres

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

A_{net50} = net cross-sectional area, in cm^2

$I_{y-net50}$ = net moment of inertia about y-axis, in cm^4

$I_{z-net50}$ = net moment of inertia about z-axis, in cm^4

(e) For cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2z}\left[\left(\sigma_E + \sigma_{ET}\right) - \sqrt{\left(\sigma_E + \sigma_{ET}\right)^2 - 4z\,\sigma_E\sigma_{ET}}\right]$$

where

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see Pt 10, Ch 1, 18.5 Other structures 18.5.1*

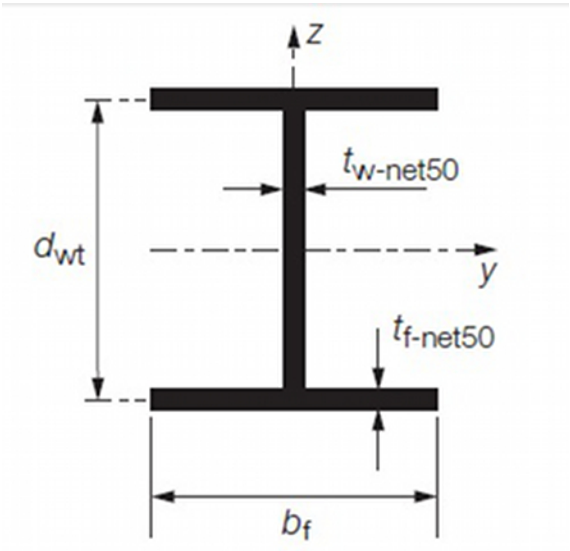
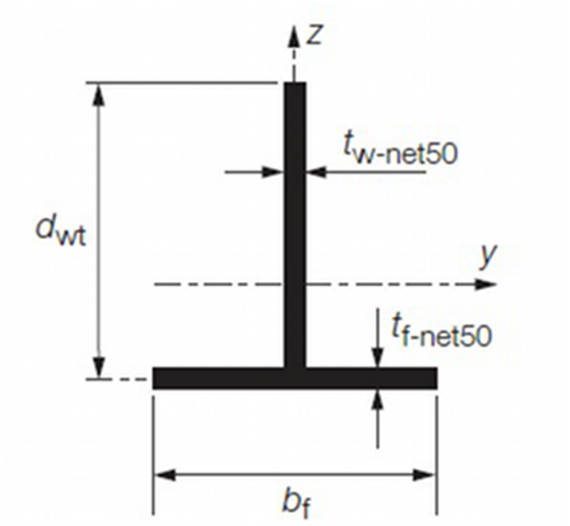
A_{net50} = net cross-sectional area, in cm^2

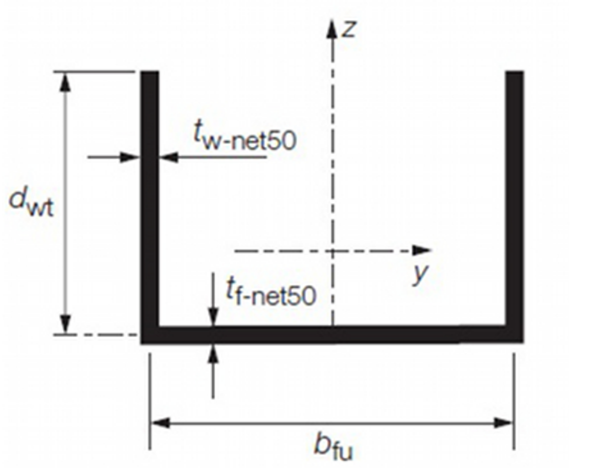
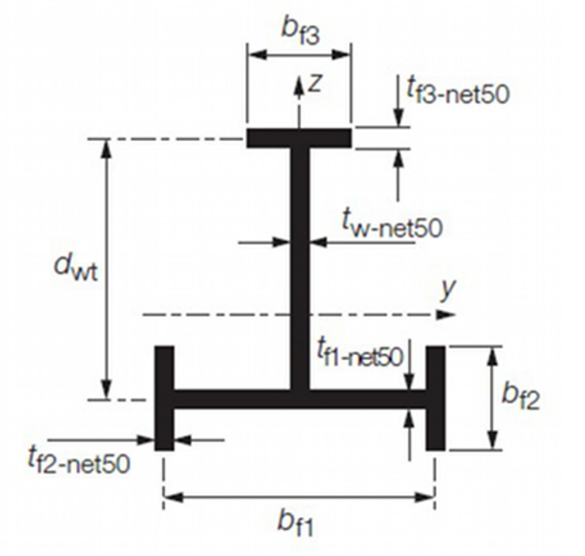
$I_{pol-net50}$ = net polar moment of inertia about the shear centre of cross-section, as defined in *Pt 10, Ch 1, 18.5 Other structures 18.5.1*

σ_{ET} = elastic torsional buckling stress, as defined in *Pt 10, Ch 1, 18.5 Other structures 18.5.1*

σ_E = elastic column compressive buckling stress, as defined in *Pt 10, Ch 1, 18.5 Other structures 18.5.1*.

Table 1.18.4 Cross-sectional properties

Double symmetrical sections	
	$I_{sv-net50} =$ $\frac{1}{3}\left(2b_f t_{f-net50}^3 + d_w t_{w-net50}^3\right) 10^{-4} cm^4$ $c_{warp} = \frac{d_{wt}^2 b_f^3 t_{f-net50}}{24} 10^{-6}\, cm^6$
Single symmetrical sections	
	$I_{sv-net50} =$ $\frac{1}{3}\left(b_f t_{f-net50}^3 + d_{wt} t_{w-net50}^3\right) 10^{-4} cm^4$ $y_0 = 0cm$ $z_0 = \frac{0,5 d_{wt}^2 t_{w-net50}}{d_{wt} t_{w-net50} + b_f t_{f-net50}} 10^{-1}\, cm$ $c_{warp} = \frac{b_f^3 t_{f-net50}^3 + 4 d_{wt}^3 t_{w-net50}^3}{144} 10^{-6}\, cm^6$ $c_{warp} = \frac{b_f^3 t_{f-net50}^3 + 4 d_{wt}^3 t_{w-net50}^3}{144} 10^{-6}\, cm^6$

<table>
<tr>
<td rowspan="2">
</td>
<td>$I_{sv-net50} =$
$\frac{1}{3}\left(b_{f1} t^3_{f1-net50} + 2 d_{wt} t^3_{w-net50}\right) 10^{-4} cm^4$</td>
</tr>
<tr>
<td>$y_0 = 0cm$
$z_0 = \frac{d^2_{wt} t_{w-net50} 10^{-1}}{2 d_{wt} t_{w-net50} + b_f t_{f-net50}}$
$- \frac{0,5 d^2_{wt} t_{w-net50} 10^{-1}}{d_{wt} t_{w-net50} + b_{fu} t_{f-net50}/6} cm$
$c_{warp} =$
$\frac{b^2_{fu} d^3_{wt} t_{w-net50}\left(3 d_{wt} t_{w-net50} + 2 b_{fu} t_{f-net50}\right)}{12\left(6 d_w t_{w-net50} + b_{fu} t_{f-net50}\right)}$
$10^{-6} cm^6$</td>
</tr>
<tr>
<td rowspan="2">
</td>
<td>$I_{sv-net50} = \frac{1}{3}\left(b_{f1} t^3_{f1-net50} + 2 b_{f2} t^3_{f2-net50}\right.$
$\left.+ b_{f3} t^3_{f3-net50} + d_{wt} t^3_{w-net50}\right) 10^{-4} cm^4$</td>
</tr>
<tr>
<td>$y_0 = 0cm$
$z_0 = z_s -$
$\frac{\left(b_{f3} d_{wt} t_{f3-net50} + 0,5 d^2_{wt} t_{w-net50}\right) 10^{-1}}{d_{wt} t_{w-net50} + b_{f1} t_{f1-net50} + 2 b_{f2} t_{f2-net50} + b_{f3} t_{f3-net50}}$
cm
$c_{warp} =$
$I_{f1} z^2_s + \frac{I_{f2} b^2_{f1}}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2 cm^6$
$I_{f1} = \left(\frac{\left(b_{f1} - t_{f2-net50}\right)^3 t_{f1-net50}}{12}\right.$
$\left.+ \frac{b_{f2} t_{f2-net50} b^2_{f1}}{2}\right) 10^{-4} cm^4$
$I_{f2} = \frac{b^3_{f2} t_{f2-net50}}{12} 10^{-4} cm^4$
$I_{f3} = \frac{b^3_{f3} t_{f3-net50}}{12} 10^{-4} cm^4$
$z_s = \frac{I_{f3} d_{wt}}{I_{f1} + I_{f3}} 10^{-1} cm$</td>
</tr>
<tr>
<td colspan="2">NOTE</td>
</tr>
</table>

All dimensions of thickness, breadth and depth are in mm. Cross-sectional properties not covered by this Table are to be obtained by direct calculation.

18.5.2 **Corrugated bulkheads.**

(a) Local buckling of a unit flange of corrugated bulkheads is to be controlled according to *Pt 10, Ch 1, 18.2 Buckling of plates 18.2.1*, for Case 1, as shown in *Pt 10, Ch 1, 18.1 General 18.1.2*, applying stress ratio ψ = 1,0.

(b) The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling according to *Pt 10, Ch 1, 18.5 Other structures 18.5.1* (e.g. horizontally corrugated longitudinal bulkheads, vertically corrugated bulkheads subject to localised vertical forces). End constraint factor corresponding to pinned ends is to be applied, except for fixed end support to be used in way of stool with width exceeding two times the depth of the corrugation.

■ *Section 19* **Fatigue**

19.1 General

19.1.1 The fatigue life is to be assessed in accordance with the LR ShipRight Procedure for Ship Units and *Pt 4, Ch 5, 5 Fatigue design*.

19.2 Factors of safety on fatigue life

19.2.1 The factors of safety defined in *Pt 4, Ch 5, 5.6 Factors of safety on fatigue life* are to be applied to the hull structure. Examples are given in *Pt 10, Ch 1, 19.2 Factors of safety on fatigue life 19.2.1*.

Table 1.19.1 Example factors of safety on fatigue life for hull structure

Location	Inspectable/repairable?	Substantial consequence of failure?	Fatigue life factor
Bilge keel in way of ballast tanks or void spaces	Wet (OIWS)	No (no pollution)	2
Bilge keel	Wet (OIWS)	Yes (pollution)	4
LNG pump tower attachment points (top dome penetrations and bottom base support penetrations)	No (covered by insulation)	Yes (loss of primary and secondary barriers)	10
LNG pump tower	Dry	Yes (loss of primary and secondary barriers)	2
Bottom longitudinal stiffener end connections inway of ballast tanks or void spaces	Dry	No (no pollution)	1
Bottom longitudinal stiffener end connections	Dry	Yes (pollution)	2
Double hull hopper knuckle connection	Dry	No (no pollution)	1

Stiffened plate module supports attachment to upper deck	Dry	No	1
Lattice module supports attachment to upper deck	Dry	Yes	2
Lattice module supports attachment to upper deckwith single member redundancy	Dry	No	1
Hull structure bounding membrane LNG tanks	Equivalent to wet (repair will damage insulation)	No	2
Penetrations in upper deck for LNG tank domes	No (covered by seal)	No	3

■ *Section 20* Stiffness and Proportions

20.1 Structural Elements

20.1.1 General

(a) All structural elements are to comply with the applicable slenderness or proportional ratio requirements in *Pt 10, Ch 1, 20.2 Plates and Local Support Members*.

20.2 Plates and Local Support Members

20.2.1 Proportions of plate panels and local support members

(a) The net thickness of plate panels and stiffeners is to satisfy the following criteria:

(i) plate panels

$$t_{\text{net}} \geq \frac{s}{C}\sqrt{\frac{\sigma_{\text{yd}}}{235}}$$

(ii) Stiffener web plate

$$t_{\text{w}-\text{net}} \geq \frac{d_{\text{w}}}{C_{\text{w}}}\sqrt{\frac{\sigma_{\text{yd}}}{235}}$$

(iii) flange/face plate

$$t_{\text{f}-\text{net}} \geq \frac{b_{\text{f}-\text{out}}}{C_{\text{f}}}\sqrt{\frac{\sigma_{\text{yd}}}{235}}$$

Where:

s plate breadth, in mm, taken as the spacing between the stiffeners

t_{net} net thickness of plate, in mm

d_w gross depth of stiffener web, in mm, as given in *Pt 10, Ch 1, 20.2 Plates and Local Support Members 20.2.1*

t_{w-net} net web thickness, in mm

b_{f-out} gross breadth of flange outstands, in mm, as given in *Pt 10, Ch 1, 20.2 Plates and Local Support Members 20.2.1*

t_{f-net} net flange thickness, in mm

C, C_w, C_f slenderness coefficients, as given in *Pt 10, Ch 1, 20.2 Plates and Local Support Members 20.2.1*

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 1.20.1 Slenderness Coefficients

Item		Coefficient
Plate panel, C	Hull envelope and tank boundaries	100
	Other structure	125
Stiffener web plate, C_w	Angle and T profiles	75
	Bulb profiles	41
	Flat bars	22
Flange/face plate, C_f *see* Note 1	Angle and T profiles	12

Note

1. The total flange breadth, b_f, for angle and T profiles is not to be less than: $b_f = 0.25 d_w$

Where:

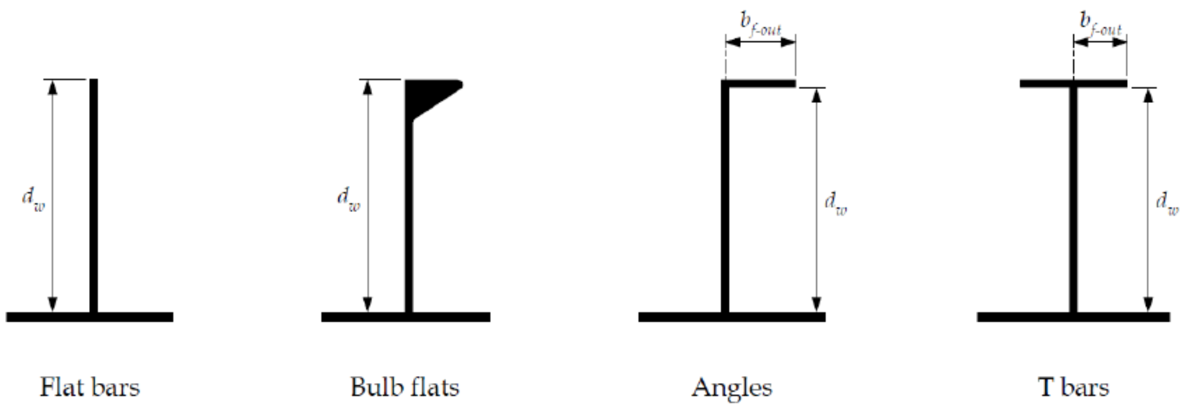
t_{net} net thickness of plate, in mm

d_w gross depth of web plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

$b_{f\text{-}out}$ gross breadth of flange outstands, in mm

$t_{f\text{-}net}$ net flange thickness, in mm



■ *Section 1* General

1.1 Application

1.1.1 This Section provides the design load combinations for the scantling calculations. The loads cover load scenarios for all modes of operation dividing the loads into static load components, dynamic load components, sloshing loads and impact loads. The loads are applicable to ship units of conventional hull form and proportions. If the form and proportions of the hull are outside of those for conventional ship type units then special consideration of the ship motions may be required. Details of the proposed hull design are to be submitted for consideration, and it is recommended this is done at as early a stage as possible.

1.1.2 The values of motions, accelerations and sloshing loads may be derived from direct calculation or obtained from model testing. These should be assessed in relation to Lloyd's Register's (LR) own direct calculation procedures.

1.2 Definitions

1.2.1 **Coordinate system.**

(a) The applied coordinate system used within these Rules is defined with respect to the right-hand coordinate system.

1.2.2 **Sign conventions.**

(a) Positive motions, as shown in *Pt 10, Ch 2, 1.2 Definitions 1.2.3*, are defined as:

- (i) positive surge is translation along positive x-axis (forward);
- (ii) positive sway is translation along positive y-axis (towards port side of vessel);
- (iii) positive heave is translation along positive z-axis (upwards);
- (iv) positive roll is starboard down and port side up;
- (v) positive pitch is bow down and stern up;
- (vi) positive yaw is bow rotating towards port side of vessel and stern towards starboard side.

(b) Positive accelerations are defined as:

- (i) positive longitudinal acceleration is acceleration along positive x-axis (forward);
- (ii) positive transverse acceleration is acceleration along positive y-axis (towards port side of vessel);
- (iii) positive vertical acceleration is acceleration along positive z-axis (upwards).

(c) The sign convention of positive vertical hull girder shear force is shown in *Pt 10, Ch 2, 1.2 Definitions 1.2.3*.

(d) The sign conventions of positive hull girder bending moments are shown in *Pt 10, Ch 2, 1.2 Definitions 1.2.3* and *Pt 10, Ch 2, 1.2 Definitions 1.2.3*, and are defined as:

- (i) positive vertical bending moment is a hogging moment and negative vertical bending moment is a sagging moment;
- (ii) positive horizontal bending moment is tension on the starboard side and compression on the port side.

1.2.3 **Density.**

(a) The density is not to be taken as less than minimum density value, as defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.3*.

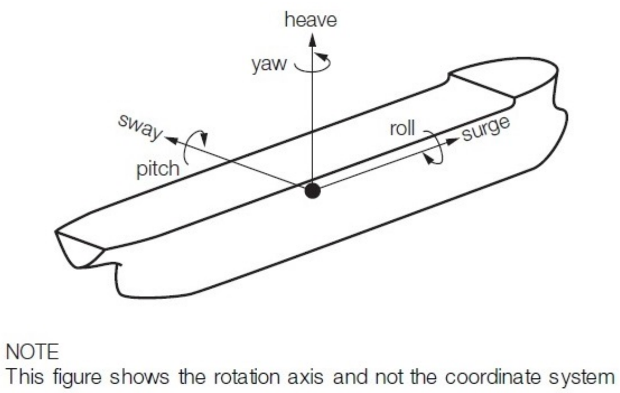


Figure 2.1.1 Definition of positive motions

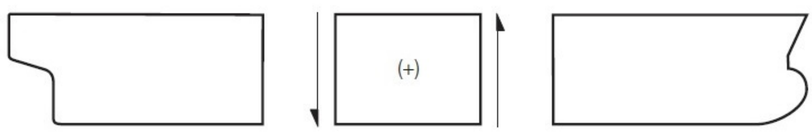


Figure 2.1.2 Positive vertical shear force

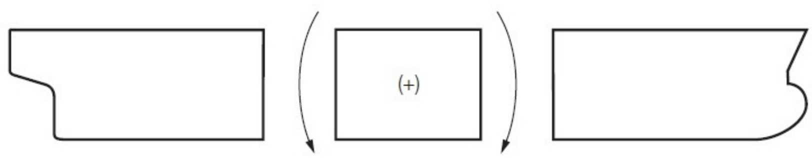


Figure 2.1.3 Positive vertical bending moment

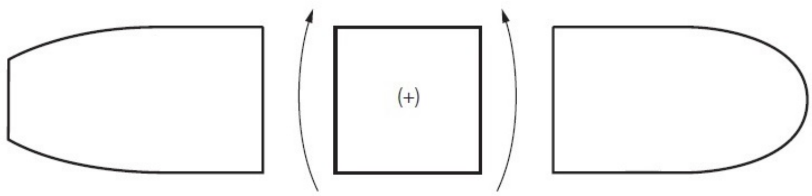


Figure 2.1.4 Positive horizontal bending moment

Table 2.1.1 Minimum density of liquid for strength and fatigue assessment

Liquid	Scantling and strength	Fatigue	Sloshing	Ultimate strength
Cargo oil	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Ballast water	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Sea-water, ρ_{sw}	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Condensate	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Chemicals	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Liquefied gas	Maximum density of the liquefied gas	Mean density of the liquefied gas	Maximum density of the liquefied gas	Maximum density of the liquefied gas

■ *Section 2*
Static load components

2.1 Symbols

2.1.1 For the purposes of this Section, the following symbols apply:

L = Rule length, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

B = moulded breadth, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

D = moulded depth, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

C_{wv} = wave coefficient, as defined in *Pt 10, Ch 2, 3.1 Symbols*

C_b = block coefficient, as defined in *Pt 4, Ch 1, 5 Definitions*

ρ = density, tonnes/m^3, as defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.3*

g = acceleration due to gravity, 9,81 m/s^2

$M_{\mathrm{sw-perm-sea}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm

$M_{\mathrm{sw-perm-oper}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm

$M_{\mathrm{sw-perm-maint}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/maintenance condition, in kNm

$Q_{\mathrm{sw-perm-sea}}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN

$Q_{\mathrm{sw-perm-oper}}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN

$Q_{\mathrm{sw-perm-maint}}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN

l_{tk} = length of cargo tank under consideration, in metres

T_{sc} = deep load draught, in metres, is the maximum draught on which the scantlings are based

V_{CT} = volume of centreline cargo tank under consideration, in m^3

V_{ST} = volume of side cargo tank under consideration, in m^3

2.2 Static hull girder loads

2.2.1 Permissible hull girder still water bending moment and shear force.

(a) The designer is to provide the permissible hull girder hogging and sagging still water bending moment limits for the transit condition, $M_{\mathrm{sw-perm-sea}}$, operational condition, $M_{\mathrm{sw-perm-oper}}$, and inspection/maintenance condition, $M_{\mathrm{sw-perm-maint}}$.

(b) The designer is to provide the permissible hull girder positive and negative still water shear force limits for the transit condition, $Q_{\mathrm{sw-perm-sea}}$, operational condition, $Q_{\mathrm{sw-perm-oper}}$, and inspection/maintenance condition, $Q_{\mathrm{sw-perm-maint}}$.

(c) The permissible hull girder still water bending moment and shear force limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks and at significant structural discontinuities, including internal turrets.

(d) The permissible hull girder still water bending moment envelope is given by linear interpolation between values at the longitudinal position given in *Pt 10, Ch 2, 2.2 Static hull girder loads 2.2.1*.

(e) The permissible hull girder still water bending moment and shear force envelopes are to be included in the loading manual as required in *Pt 4, Ch 3, 1.1 Application 1.1.3* and *Pt 4, Ch 3, 1.1 Application 1.1.4*.

2.2.2 New build.

(a) Loadings patterns representative of the loading conditions for all modes of operation are to be assessed considering those cases which will induce the largest forces in the hull structure.

(b) The static loading conditions to be used in combinations with the applicable dynamic loads in Section 6 should be appropriate for the intended operation of the unit. In general, they should include:

- homogeneous full load;
- emergency ballast;
- ‘chequer-board’ loading;
- all cargo tanks full with any two adjacent cargo tanks empty (this is to allow repair of any tank boundary whilst in service); and
- all cargo tanks empty with any one cargo tank full;

- most onerous partial loading conditions as applicable.

2.2.3 **Conversions and redeployments.**

(a) The loading conditions should be as for new build units, *see Pt 10, Ch 2, 2.2 Static hull girder loads 2.2.2*, suitably modified to take account of the following:

- Loading limitations previously assigned prior to conversion/redeployment.
- Where the loading conditions defined for new build units are too restrictive or too onerous.

2.3 Local static loads

2.3.1 **General.**

(a) The following static loads are to be considered, as appropriate:

(i) static sea pressure;
(ii) static tank pressure;
(iii) tank overpressure, in addition to the static tank pressure when appropriate;
(iv) static deck load;
(v) accidental pressure.

2.3.2 Static pressure.

(a) The static pressures for the static loads defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.1*are given in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*.

2.3.3 **Static deck loads from heavy units.**

(a) The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting on the mass. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat} , is to be taken as:

$F_{\text{stat}} = m_{\text{un}}\, g$ kN

where

m_{un} = mass of unit, in tonnes.

Table 2.2.1 Static load pressures

Load cases	Static pressure, in kN/m^2
(a) Static sea pressure	$P_{\text{hys}} = \rho_{\text{sw}}\, g\left(T_{\text{LC}} - z\right)$
(b) Static tank pressure	$P_{\text{in - tk}} = \rho\, g\, z_{\text{top}}$
(c) Static tank pressure + overpressure	$P_{\text{in - air}} = \rho_{\text{sw}}\, g\, z_{\text{air}}$ $P_{\text{in - test}} = \max\left(\rho_{\text{sw}}\, \mathrm{g}\, z_{\text{test}}, \rho_{\text{sw}}\, \mathrm{g}\, z_{\text{top}} + \mathrm{P}_{\text{value}}\right)$ *see* Note 2
(d) Static deck pressure	$P_{\text{stat}} = P_{\text{deck}}$
(e) Accidental pressure	$P_{\text{in - flood}} = \rho_{\text{sw}}\, g\, z_{\text{fd}}$
Symbols	
z = vertical coordinate of load point, in metres, and is not to be greater than T_{LC} , *see Figure 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure* ρ_{sw} = density of sea-water, 1,025 tonnes/m^3 *see* Note 2	

T_{LC} = draught in the loading condition being considered, in metres

z_{top} = vertical distance from highest point of tank, excluding small hatchways, to the load point, *see Figure 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure*, in metres

z_{air} = vertical distance from top of air pipe or overflow pipe to the load point, whichever is the lesser, *see Figure 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure*, in metres

= $z_{top} + h_{air}$

h_{air} = height of air pipe or overflow pipe, in metres, is not to be taken less than 0,76 m above highest point of tank, excluding small hatchways. For tanks with tank top below the weather deck, the height of air pipe or overflow pipe is not to be taken less than 0,76 m above deck at side, unless a lesser height is approved by the Flag Administration. *See also Figure 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure*

z_{fd} = vertical distance from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given, in metres

z_{test} = vertical distance to the load point is to be taken as defined in *Table 2.2.2 Testing load height*

P_{valve} = setting of pressure relief valve, if fitted, is not to be taken less than 25 kN/m^2

P_{deck} = uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components, in kN/m^2. P_{deck} is not to be taken less than 16 kN/m^2

NOTE

1. The added overpressure due to sustained liquid through the air pipe or overflow pipe in the case of overfilling, P_{drop} , is to be taken as 25 kN/m^2. Additional calculations may be required where piping arrangements may lead to a higher pressure drop, e.g. long pipes or arrangements such as bends and valves.

2. The density ρ_{tank} is not to be taken greater than the value defined in *Table 2.1.1 Minimum density of liquid for strength and fatigue assessment*. For example, where a tank is not designed to be filled or tank-tested with sea water e.g. liquefied gas tanks, the greater of the density of the testing liquid and the actual liquid to be stored is to be used to assess the tank.

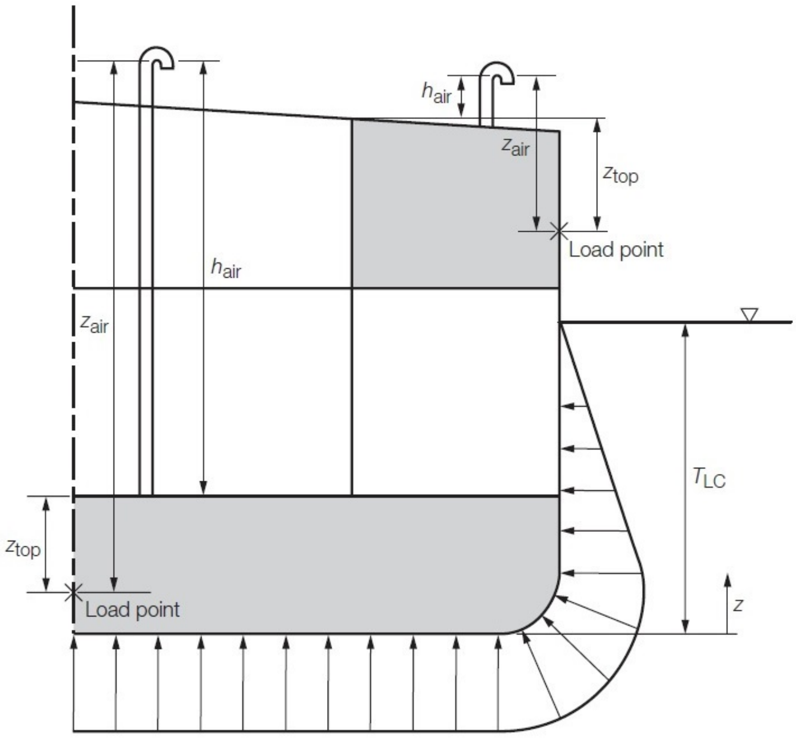


Figure 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure

Table 2.2.2 Testing load height

Compartment or structure to be tested	Testing load height, in metres
Cargo tanks and other tanks designed for liquid filling, including double bottom tanks, hopper side tanks, topside tanks, double side tanks, deep tanks, fuel oil bunkers, slop tanks, fresh water tanks, lube oil tanks, fore and after peaks used as tanks and/or fitted with air pipe. Cofferdams	The greater of the following: $z_{test} = z_{top} + h_{air}$ $z_{test} = z_{top} + 2,4$ $z_{test} = z_{top} + z_{valve}$
Fore and aft peaks not used as tanks and not fitted with air pipe	To be tested for tightness, *see* Note
Watertight doors below freeboard deck	To be tested for tightness, *see* Note
Chain locker	$z_{test} = z_{top}$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure
Symbols are as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*	
z_{valve} = equivalent head of pressure safety valve, in metres $= 10P_{valve}$ P_{valve} = setting pressure, in bar, of pressure safety valve where applicable	

NOTE

When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.

■ *Section 3* Dynamic load components

3.1 Symbols

3.1.1 For the purposes of this Section, the following symbols apply:

L = Rule length, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

B = moulded breadth, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

D = moulded depth, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

C_{b} = block coefficient, as defined in *Pt 4, Ch 1, 5 Definitions*

C_{wv} = wave coefficient to be taken as:

= 0,0412*L* + 4,0 for *L* < 90

= $10{,}75 - \left(\frac{300 - L}{100}\right)^{\frac{3}{2}}$ for 90 ≤ *L* ≤ 300

= 10,75 for 300 < *L* ≤ 350

= $10{,}75 - \left(\frac{L - 350}{150}\right)^{\frac{3}{2}}$ for 350 < *L* ≤ 500

GM = metacentric height, in metres, as defined in *Pt 10, Ch 2, 3.2 General 3.2.3*

k_{r} = roll radius of gyration, in metres, as defined in *Pt 10, Ch 2, 3.2 General 3.2.3*

f_{bk} = 1,2 for units without bilge keel

= 1,0 for units with bilge keel

$T\theta$ = roll period, in seconds, as defined in *Pt 10, Ch 2, 3.5 Motions 3.5.2*

θ = roll amplitude, in degrees, as defined in *Pt 10, Ch 2, 3.5 Motions 3.5.2*

$T\phi$ = pitch period, in seconds, as defined in *Pt 10, Ch 2, 3.5 Motions 3.5.3*

ϕ = pitch amplitude, in degrees, as defined in *Pt 10, Ch 2, 3.5 Motions 3.5.3*

R_{roll} = $z - \left(\frac{D}{4} + \frac{T_{\mathrm{LC}}}{2}\right) \text{or } z - \left(\frac{D}{2}\right)$

,whichever is the greater, in metres

R_{pitch} = pitch radius and is to be taken as the greater of

$z-\left(\frac{D}{4}+\frac{T_{\text{LC}}}{2}\right)$ or $z-\left(\frac{D}{2}\right)$, in metres

f_{T} = $\frac{T_{\text{LC}}}{T_{\text{sc}}}$

T_{sc} = deep load draught, in metres

T_{LC} = draught in the loading condition being considered, in metres

a_0 = common acceleration parameter, as defined in *Pt 10, Ch 2, 3.6 Accelerations 3.6.2*

a_{v} = envelope vertical acceleration, in m/s^2, as defined in *Pt 10, Ch 2, 3.6 Accelerations 3.6.3*, at tank centre of gravity

a_{t} = envelope transverse acceleration, in m/s^2, as defined in *Pt 10, Ch 2, 3.6 Accelerations 3.6.4*, at tank centre of gravity

a_{lng} = envelope longitudinal acceleration, in m/s^2, as defined in *Pt 10, Ch 2, 3.6 Accelerations 3.6.5*, at tank centre of gravity

a_{heave} = vertical acceleration due to heave, is to be taken as:

= a_0 g m/s^2

$a_{\text{pitch}-\text{z}}$ = vertical acceleration due to pitch, is to be taken as:

= $\left(0,3+\frac{L}{325}\right)\varphi\left(\frac{\pi}{180}\right)\left(\frac{2\,\pi}{T_{\theta}}\right)^2|x-0,45L|\ \text{m}/\text{s}^2$

$a_{\text{roll}-\text{z}}$ = vertical acceleration due to roll, is to be taken as:

= $1,2\,\theta\left(\frac{\pi}{180}\right)\left(\frac{2\,\pi}{T_{\theta}}\right)^2|y|$ m/s^2

a_{sway} = transverse acceleration due to sway and yaw, is to be taken as:

= 0,3g a_0 m/s^2

$a_{\text{roll}-\text{y}}$ = transverse acceleration due to roll, is to be taken as:

= $\theta\left(\frac{\pi}{180}\right)\left(\frac{2\,\pi}{T_{\theta}}\right)^2 R_{\text{roll}}$ m/s^2

a_{surge} = longitudinal acceleration due to surge, is to be taken as:

= $\varphi\left(\frac{\pi}{180}\right)\left(\frac{2\,\pi}{T_{\varphi}}\right)^2 R_{\text{pitch}}$ m/s^2

ρ = density, tonnes/m$_3$, as defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.3*

g = acceleration due to gravity, 9,81 m/s^2

x = longitudinal coordinate of load point under consideration, in metres

y = transverse coordinate of load point under consideration, in metres

z = vertical coordinate of load point under consideration, in metres

x_0 = longitudinal coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank length at the top of the tank, in metres

y_0 = transverse coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank breadth at the top of the tank, in metres

z_0 = vertical coordinate of reference point, for dynamic tank pressures is to be taken as the highest point in the tank, in metres

f_{prob} = probability factor, as defined in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob* , as appropriate

$f_{\text{Env - pitch}}$ = environmental factor due to pitch motion, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2*

$f_{\text{Env - av}}$ = environmental factor due to vertical acceleration, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.6 Accelerations 3.6.3*

$f_{\text{Env - at}}$ = environmental factor due to transverse acceleration, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.6 Accelerations 3.6.4*

$f_{\text{Env - alng}}$ = environmental factor due to longitudinal acceleration, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.6 Accelerations 3.6.5*

$f_{\text{Env - Mwv}}$ = environmental factor due to vertical wave bending moment, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1*

$f_{\text{Env - Mwv - h}}$ = environmental factor due to horizontal wave bending moment, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1*

$f_{\text{Env - Qwv}}$ = environmental factor due to vertical wave shear force, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.2*

$f_{\text{Env - Pex - dyn}}$ = environmental factor due to dynamic wave pressure, as defined in *Pt 10, Ch 2, 3.3 Environmental factors 3.3.2* and *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2*.

3.2 General

3.2.1 Basic components.

(a) Formulae for unit loads, motions and accelerations are given in this sub-Section. Values calculated in accordance with the LR ShipRight Procedure for Ship Units may be used instead.

(b) Formulae for the envelope value of the basic dynamic load components are also given. The basic load components are:

- (i) vertical wave bending moment and shear force;
- (ii) horizontal wave bending moment;
- (iii) dynamic wave pressure;
- (iv) dynamic tank pressures.

3.2.2 Envelope load values.

(a) The envelope loads for scantling requirements and strength assessment are based on the specific return period given in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*.

3.2.3 Metacentric height and roll radius of gyration for FPSO.

(a) The metacentric height, *GM*, and roll radius of gyration, k_r , should be calculated for typical loading conditions as indicated in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*. For the initial design of units storing oil in bulk (e.g. FPSOs), the values in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6* may be used. The values in *Pt 10,*

Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6 for deep draught condition may be used for the initial design of units for the flooded load scenario, *see Pt 10, Ch 2, 5.1 Flooded condition*.

3.3 Environmental factors

3.3.1 The environmental factors are used to derive the dynamic load components for the intended site-specific condition and for the transit condition.

3.3.2 For initial design purposes, the environmental factors considering motion are specified in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*. For sites not included in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*, the factors are to be calculated in accordance with the LR ShipRight Procedure for Ship Units.

3.3.3 The environmental factors for the operational condition may be used for the initial design of units for the inspection/ maintenance case. The environmental factors for the deep draught for the operational condition may be used for the initial design of units for the flooded case.

3.4 Return periods and probability factor, f_{prob}

3.4.1 For each load condition, the environmental loads for scantling requirements and strength assessment are to be determined at the return periods specified in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*.

3.4.2 In no case are the environmental loads used for the assessment of the hull structure for on-site operation, inspection/ maintenance, restricted service area transit, delivery voyage and flooding to be less than 50 per cent of the 25-year return period dynamic loads defined for unrestricted worldwide transit service.

3.4.3 Environmental loads derived for the same wave environment, but at a different return period, may be adjusted to the required return period by use of the probability factor f_{prob} . Therefore, when the environmental loads are derived for the return periods specified in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*, f_{prob} is to be taken as equal to 1. Probability factors should be derived in accordance with the LR ShipRight Procedure for Ship Units.

3.4.4 The site-specific environmental factors, given in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*, give 100-year return period loads for the locations specified using all-year wave data. Therefore, when using these factors for the on-site operation condition, f_{prob} is to be taken as equal to 1.

3.4.5 At the request of the Owner and when consistent with the operational philosophy of the unit, seasonal environmental data may be used to derive the environmental loads for the inspection/maintenance condition. Alternatively, the all-year loads derived for the on-site operation condition may be used for the inspection/maintenance assessment, in conjunction with the probability factor derived to account for the difference between all-year loads and seasonal loads.

3.4.6 In no case are the environmental loads used for the assessment of the hull structure for on-site operation, inspection/ maintenance and flooding in a harsh environment to be less than the 25-year return period dynamic loads defined for unrestricted worldwide transit, calculated for a vessel of the same particulars with metacentric height, GM, and roll radius of gyration, k_{r} , taken from *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*.

Table 2.3.1 *GM* and k_r

Condition	T_{LC}	*GM*	k_{r}
Deep draught condition, usually a full load condition	above 0,9 T_{sc}	0,12*B*	0,35*B*
Partial load draught condition, usually a part load-part ballast condition	0,6 T_{sc}	0,24*B*	0,40*B*
Light draught condition, usually a ballast condition	0,5 T_{sc}	0,33*B*	0,45*B*
NOTE Values for intermediate draughts may be calculated by linear interpolation.			

Table 2.3.2 Environmental factors

Unit size and operating condition	Environment *see* Note 2,	Draught	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	$f_{\mathrm{Env-Pex-dyn}}$, *see* Note 1		
			Pitch	a_{v}	a_{t}	a_{lng}	M_{wv}	$M_{\mathrm{wv-h}}$	Q_{wv}	at, and aft of, midship	at 0,85*L*	at FP
Aframax or VLCC Transit	Unrestricted worldwide	N/A	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Aframax Weather vaningr	West of Shetland Is.	Deep	1,3	0,8	1,2	1,4	1,7	0,8	2,0	1,0	1,2	1,6
		Light	1,3	0,8	1,5	1,2	1,3	1,0	2,0	1,0	1,0	1,6
	North Sea	Deep	1,2	0,5	1,2	1,4	1,6	0,8	1,75	0,75	1,0	1,6
		Light	1,2	0,7	1,5	1,2	1,2	1,0	1,75	1,0	1,0	1,6
	Brazil Campos Basin	Deep	0,6	0,5	1,0	0,65	0,75	0,5	0,75	0,5	0,5	0,8
		Light	0,6	0,5	1,65	0,6	0,5	1,0	0,8	0,8	0,75	0,75
	Western Australia (non-cyclonic)	Deep	0,5	0,5	0,65	0,6	0,65	0,55	0,7	0,5	0,5	0,75
		Light	0,5	0,5	0,75	0,5	0,5	0,55	0,7	0,5	0,5	0,7
VLCC Weather vaning	Brazil Campos Basin	Deep	0,55	0,50	0,50	0,50	0,60	0,50	0,90	0,60	0,60	0,70
		Light	0,60	0,50	0,50	0,65	0,50	0,50	0,65	0,55	0,55	0,60
	Western Australia (non-cyclonic)	Deep	0,50	0,50	0,50	0,50	0,50	0,50	0,70	0,60	0,60	0,60
		Light	0,50	0,50	0,50	0,55	0,50	0,50	0,60	0,50	0,50	0,55
VLCC spread moored	Nigeria	Deep	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
		Light	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50

NOTES

1. Values at intermediate locations may be calculated by linear interpolation. The values for weather vaning units are applicable to units that vane about the bow.

2. The geographic locations of the sites at which long-term environmental data has been used to derive the site-specific environmental factors are shown as follows:

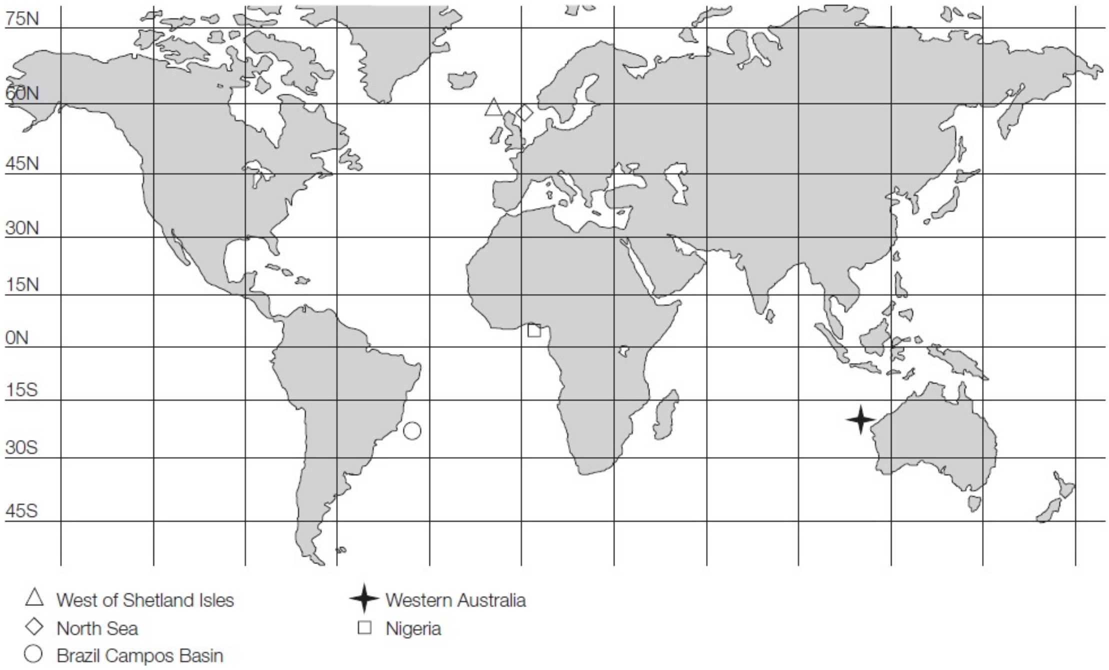


Table 2.3.3 Return periods for scantling requirements and strength assessment

Operational condition	Transit			Normal on-site operation	Inspection/maintenance	Accidental
	Delivery voyage	Restricted Service area	Unrestricted World-wide			
Return period	1 year with all year data or 10 year with Seasonal data	25 years	25 years	100 years	100 years with all year data or 100 years with seasonal data where consistent with the operation of the unit *see also Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.5* and Note 1	1 year
Environment	World-wide or Owner-defined Transit route	Restricted service area	World-wide	Site-specific	Site-specific	Site-specific

Note

1. Alternative return periods will be specially considered based on the duration of the inspection/maintenance period and the site specific environment.

3.5 Motions

3.5.1 General.

(a) The envelope values for unit motions are to be taken at the specific return period specified in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*.

3.5.2 Roll Motion.

(a) The roll period, T_θ, is to be taken as:

$$T_{\theta} = \frac{2,3\,\pi\,k_{\mathrm{r}}}{\sqrt{g\,GM}}\ \text{seconds}$$

In the event of the roll period being equal to 25 seconds or more, in addition to first-order wave forces, roll excitation by environmental forces including second-order wave forces and dynamic wind gusts are to be considered as applicable. The calculation method is to be acceptable to LR.

(b) The roll amplitude, θ, is to be taken as:

$$\theta = \frac{9000\left(1,25 - 0,025T_{\theta}\right)f_{\mathrm{bk}}}{(B + 75)\,\pi}\ \text{degrees}$$

3.5.3 **Pitch motion.**

(a) The characteristic pitch period, $T\varphi$, is to be taken as:

$$T_{\varphi} = \sqrt{\frac{2\,\pi\ \lambda_{\varphi}}{g}}\ \text{seconds}$$

where

λ_{φ} = 0,6 (1 + f_{T}) L

(b) The pitch amplitude, ϕ, is to be taken as:

ϕ = 1350 $L^{-0,94}$ [1 + $F_{\mathrm{n}}^{1,2}$] degrees

where

F_{n} = is the non-dimensional Froude number and is defined as:

$$F_{\mathrm{n}} = \frac{0,514V}{\sqrt{g\,L_{\mathrm{wl}}}}$$

where

V = is the vessel speed, in knots

= zero at fixed locations

= maximum transit speed for transit condition, *see also Pt 10, Ch 1, 1.3 Application of transit conditions*

L_{wl} = is the length on the waterline at the load case draught, in metres.

3.6 Accelerations

3.6.1 **General.**

(a) The envelope values for combined translational accelerations due to motion in six degrees of freedom are given. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

3.6.2 **Common acceleration parameter.**

(a) The common acceleration parameter, a_0, is to be taken as:

$$a_0 = \left(1,58 - 0,47C_{\mathrm{b}}\right)\left(\frac{2,4}{\sqrt{L}} + \frac{34}{L} + \frac{600}{L^2}\right)$$

3.6.3 **Vertical acceleration.**

(a) The envelope vertical acceleration, a_{v}, at any position, is to be taken as:

$$a_{\mathrm{v}} = f_{\mathrm{prob}} f_{\mathrm{Env-av}} \sqrt{a_{\mathrm{heave}}^2 + a_{\mathrm{pitch-z}}^2 + a_{\mathrm{roll-z}}^2}\ \text{m/s}^2$$

3.6.4 **Transverse acceleration.**

(a) The envelope transverse acceleration, a_{t}, at any position, is to be taken as:

$$a_t = f_{prob} f_{Env-at} \sqrt{a^2_{sway} + \left(g \sin\theta + a_{roll-y}\right)^2} \text{ m/s}^2$$

3.6.5 **Longitudinal acceleration.**

(a) The envelope longitudinal acceleration, a_{lng} , at any position, is to be taken as:

$$a_{lng} = 0,7 f_{prob} f_{Env-alng} \sqrt{a^2_{surge} + \left(\frac{L}{325}\left(g \sin 4 + a_{pitch-x}\right)\right)^2} \text{ m/s}^2$$

3.7 Dynamic hull girder loads

3.7.1 **Vertical and horizontal wave bending moments.**

(a) The envelope hogging vertical wave bending moment, M_{wv-hog} , and sagging vertical wave bending moment, M_{wv-sag} , and horizontal wave bending moment, M_{wv-h} , are to be taken as:

- Vertical wave bending moment

$$M_{wv-hog} = f_{prob} f_{Env-Mwv} 0,19 f_{wv-v} C_{wv} L^2 B C_b \text{ kNm}$$

$$M_{wv-sag} = -f_{prob} f_{Env-Mwv} 0,11 f_{wv-v} C_{wv} L^2 B \left(C_b + 0,7\right) \text{ kNm}$$

- Horizontal wave bending moment

$$M_{wv-h} = f_{prob} f_{Env-Mwv-h} \left(0,3 + \frac{L}{2000}\right) f_{wv-h} C_{wv} L^2 T_{LC} C_b \text{ kNm}$$

where

f_{wv-v}, f_{wv-h} = distribution factors for vertical and horizontal wave bending moments along the vessel length, to be taken as:

= 0,0 at A.P.

= 1,0 for 0,4*L* to 0,65*L* from A.P.

= 0,0 at F.P.

intermediate values to be obtained by linear interpolation, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2*

f_{prob} = probability factor is defined in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob* , as appropriate.

3.7.2 **Vertical wave shear force.**

(a) The envelope positive and negative vertical wave shear forces, Q_{wv-pos} and Q_{wv-neg} , are to be taken as:

$$Q_{wv-pos} = 0,3 f_{prob} f_{Env-Qwv} f_{qwv-pos} C_{wv} L B \left(C_b + 0,7\right) \text{ kN}$$

$$Q_{wv-neg} = -0,3 f_{prob} f_{Env-Qwv} f_{qwv-neg} C_{wv} L B \left(C_b + 0,7\right) \text{ kN}$$

where

$f_{qwv-pos}$ = distribution factor for positive vertical wave shear force along the vessel length and is to be taken as:

= 0,0 at A.P.

= $1,59 \dfrac{C_b}{\left(C_b + 0,7\right)}$ for 0,2*L* to 0,3*L* from A.P.

= 0,7 for 0,4*L* to 0,6*L* from A.P.

= 1,0 for 0,7*L* to 0,85*L* from A.P.

= 0,0 at F.P.

$f_{qwv-neg}$ = distribution factor for negative vertical wave shear force along the vessel length and is to be taken as:

= 0,0 at A.P.

= 0,92 for 0,2L to 0,3L from A.P.

= 0,7 for 0,4L to 0,6L from A.P.

= $1{,}73 \dfrac{C_{\mathrm{b}}}{\left(C_{\mathrm{b}}+0{,}7\right)}$ for 0,7L to 0,85L from A.P.

= 0,0 at F.P.

intermediate values of $f_{\mathrm{qwv-pos}}$ and $f_{\mathrm{qwv-neg}}$ are to be obtained by linear interpolation, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2* and *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2* respectively.

3.8 Dynamic local loads

3.8.1 **General.**

(a) This Section provides the envelope values for dynamic wave pressure, dynamic tank pressure, green sea load and dynamic deck loads.

(b) The envelope dynamic wave pressures are given in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2*.

(c) The envelope green sea load given in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.3* only applies to scantling requirements and strength assessment.

(d) The envelope dynamic tank pressure is a combination of the inertial components due to vertical, transverse and longitudinal acceleration. The envelope dynamic tank pressure components are given in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.4*.

(e) The envelope dynamic deck loads are given in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.5* and *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.6*.

3.8.2 **Dynamic wave pressure.**

(a) The envelope dynamic wave pressure, $P_{\mathrm{ex-dyn}}$, is to be taken as the greater of the following:

$$P_1 = 2f_{\mathrm{prob}}f_{\mathrm{Env-Pex-dyn}}f_{\mathrm{nl-P1}}\left[\left(P_{11}+\frac{135B_{\mathrm{local}}}{4(B+75)}-1{,}2\left(T_{\mathrm{LC}}-z\right)\right)f_1+\frac{135B_{\mathrm{local}}}{4(B+75)}f_2\right]\mathrm{kN/m^2}$$

$$P_2 = 26f_{\mathrm{prob}}f_{\mathrm{Env-Pex-dyn}}f_{\mathrm{nl-P2}}\left[\left(\frac{B_{\mathrm{local}}}{8}\theta\left(\frac{\pi}{180}\right)+f_{\mathrm{T}}C_{\mathrm{b}}\frac{0{,}25B_{\mathrm{local}}+0{,}8C_{\mathrm{wv}}}{14}\left(0{,}7+\frac{2z}{T_{\mathrm{LC}}}\right)\right)f_1\right.$$
$$\left.+\left(\frac{B_{\mathrm{local}}}{8}\theta\left(\frac{\pi}{180}\right)+f_{\mathrm{T}}C_{\mathrm{b}}\frac{0{,}25B_{\mathrm{local}}}{14}\left(\frac{2z}{T_{\mathrm{LC}}}\right)\right)f_2\right]\mathrm{kN/m^2}$$

where

B_{local} = local breadth at the waterline, for considered draught, not to be taken less than 0,5B, in metres

P_{11} = ($3f_{\mathrm{s1}}$ + 0,8) C_{wv}

f_1 = $f_{\mathrm{lng}} - f_{\mathrm{lng}}\,f_2 + f_2$

f_2 = $0{,}25\left(\dfrac{4|y|}{B_{\mathrm{local}}}-1\right)$ for $|y| < 0{,}25\,B_{\mathrm{local}}$

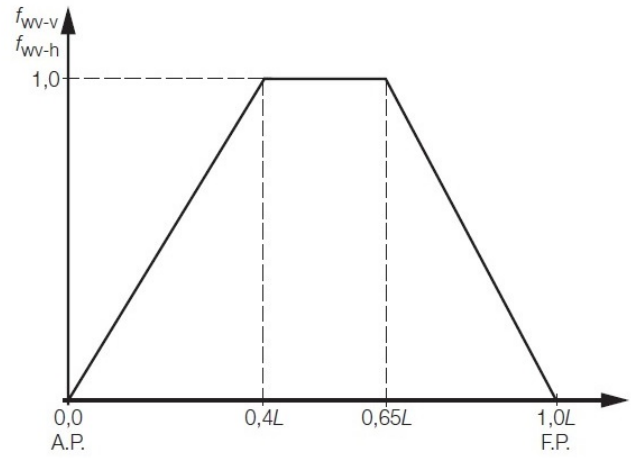


Figure 2.3.1 Vertical and horizontal wave bending moment distribution for scantling requirements and strength assessment

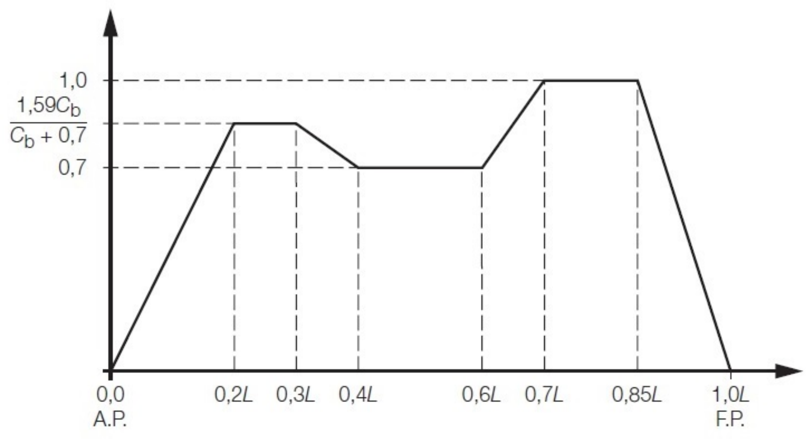


Figure 2.3.2 Positive vertical wave shear force distribution

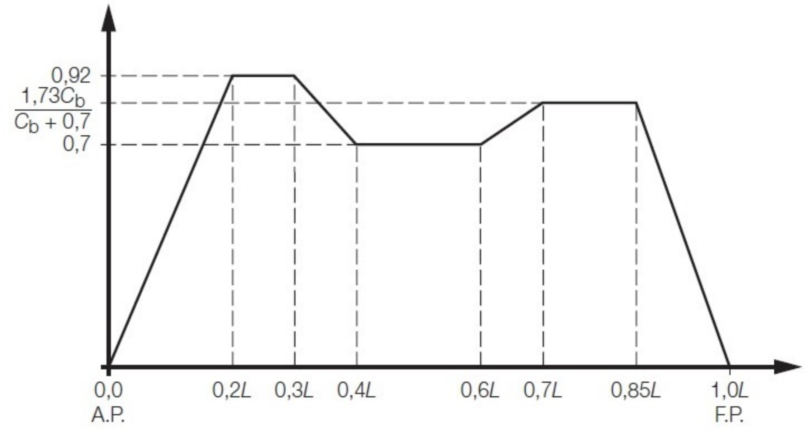


Figure 2.3.3 Negative vertical wave shear force distribution

= $\dfrac{4|y|}{B_{\text{local}}} - 1$ for $|y| \geq 0,25\ B_{\text{local}}$

$f_{s1} = C_b + \dfrac{1,33}{\sqrt{C_b}}$ at, and aft of, A.P.

= C_b between 0,2*L* and 0,7*L* from A.P.

= $C_b + \dfrac{1,33}{C_b}$ at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

f_{lng} = 1,0 at, and aft of, A.P.

= 0,7 for 0,2*L* to 0,7*L* from A.P.

= 1,0 at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

$f_{\text{nl}-\text{P1}}$, $f_{\text{nl}-\text{P2}}$ and f_{prob} are given in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2* for scantling requirements and strength assessment application.

(b) For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, $P_{\text{ex}-\text{max}}$, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.6*, and minimum dynamic wave pressure, $P_{\text{ex}-\text{min}}$, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.6*, are to be taken as:

$P_{\text{ex}-\text{max}} = P_{\text{ex}-\text{dyn}}$ kN/m^2 below still waterline

= $P_{\text{WL}} - 10\ (z - T_{\text{LC}})$ kN/m^2

for $T_{\text{LC}} < z \leq T_{\text{LC}} + \dfrac{P_{\text{WL}}}{10}$

= 0 kN/m^2 for $z > T_{\text{LC}} + \dfrac{P_{\text{WL}}}{10}$

$P_{\text{ex}-\text{min}} = -\ P_{\text{ex}-\text{dyn}}$ kN/m^2 below still waterline

= 0 kN/m^2 above still waterline

where

$P_{\text{ex}-\text{min}}$ is not to be taken as less than $-\rho_{\text{sw}} g\,(T_{\text{LC}} - z)$

where

$P_{\text{ex}-\text{dyn}}$ = envelope dynamic wave pressure, in kN/m^2, as defined in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2* with:

f_{prob} is defined in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob*

$f_{\text{nl}-\text{P1}}$ = 1 – 0,2 (f_{prob} – 0,5) but is not to be taken greater than 1,0

$f_{\text{nl}-\text{P2}} = f_\beta$ (1 – 0,375 (f_{prob} – 0,5)) but is not to be taken greater than 1,0

f_β = heading correction factor, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.1*

P_{WL} = pressure at waterline, to be taken as $P_{\text{ex}-\text{dyn}}$ at still waterline, in kN/m^2.

3.8.3 **Green sea load.**

(a) The envelope green sea load on the weather deck, P_{wdk} , is to be taken as the greater of the following:

$P_{\text{wdk}} = f_{1-\text{dk}}\,(f_{\text{op}}\,P_{1-\text{WL}} - 10z_{\text{dk}-\text{T}})$ kN/m^2

$P_{\text{wdk}} = 0{,}8\,f_{2-\text{dk}}\,(P_{2-\text{WL}} - 10z_{\text{dk}-\text{T}})$ kN/m^2

P_{wdk} = 34,3 kN/m^2

where

$f_{1-\text{dk}} = 0{,}8 + \dfrac{L}{750}$

$f_{2-\text{dk}} = 0{,}5 + \dfrac{|y|}{B_{\text{wdk}}}$

f_{op} = 1,0 at, and forward of, 0,2*L* from A.P.

= 0,8 at, and aft of, A.P.

intermediate values to be obtained by linear interpolation

$P_{1-\text{WL}} = P_1$ pressure at still waterline for considered draught, in kN/m^2, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2*

$P_{2-\text{WL}} = P_2$ pressure at still waterline for considered draught, in kN/m^2, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.2*

$z_{\text{dk}-\text{T}}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres

B_{wdk} Bwdk = local breadth at the weather deck, in metres

Where loads are available from a model test, they may be used for design purposes.

3.8.4 **Dynamic tank pressure.**

(a) The envelope dynamic tank pressure, $P_{\text{in}-\text{v}}$, due to vertical tank acceleration is to be taken as:

$P_{\text{in}-\text{v}} = \rho\,a_{\text{v}}\left(z_0 - z\right)$ kN/m^2 for strength assessment and scantling requirements.

(b) The envelope dynamic tank pressure, $P_{\text{in}-\text{t}}$, due to transverse acceleration is to be taken as:

$P_{\text{in}-\text{t}} = f_{\text{ull}-\text{t}}\,\rho\,a_{\text{t}}\left(y_0 - y\right)$ kN/m^2 for strength assessment and scantling requirements.

where

$f_{\text{ull}-\text{t}}$ = factor to account for ullage in cargo tanks, and is to be taken as:

= 0,67 for cargo tanks, including cargo tanks designed for filling with water ballast

= 1,0 for ballast and other tanks.

(c) The envelope dynamic tank pressure, $P_{\text{in} - \text{lng}}$, due to longitudinal acceleration is to be taken as:

$P_{\text{in} - \text{lng}} = f_{\text{ull} - \text{lng}} \ \rho \ a_{\text{lng}} \left(x_0 - x\right)$ kN/m^2 for scantling requirements and strength assessment

where

$f_{\text{ull} - \text{lng}}$ = factor to account for ullage in cargo tanks, and is to be taken as:

= 0,62 for cargo tanks, including cargo tanks designed for filling with water ballast

= 1,0 for ballast and other tanks.

(d) For scantling requirements and strength assessment, the simultaneous acting dynamic tank pressure, $P_{\text{in} - \text{dyn}}$, is to be taken as the summation of the components for the considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*.

3.8.5 **Dynamic deck pressure from distributed loading.**

(a) The envelope dynamic deck pressure, $P_{\text{deck} - \text{dyn}}$, on decks, inner bottom and hatch covers is to be taken as:

$P_{\text{deck} - \text{dyn}} = P_{\text{deck}} \dfrac{a_{\text{v}}}{g}$ kN/m^2

where

P_{deck} = uniformly distributed pressure on lower decks and decks within superstructure, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.2*.

3.8.6 **Dynamic loads from heavy units.**

(a) The envelope dynamic deck loads, F_{v} , F_{t} , F_{lng} , acting vertically, transversely and longitudinally on supporting structures and securing systems for heavy units of cargo, equipment or structural components are to be taken as:

$F_{\text{v}} = m_{\text{un}} \, a_{\text{v}} \, \text{kN}$

$F_{\text{t}} = m_{\text{un}} \, a_{\text{t}} \, \text{kN}$

$F_{\text{lng}} = m_{\text{un}} \, a_{\text{lng}} \, \text{kN}$

where

m_{un} = mass of unit, in tonnes.

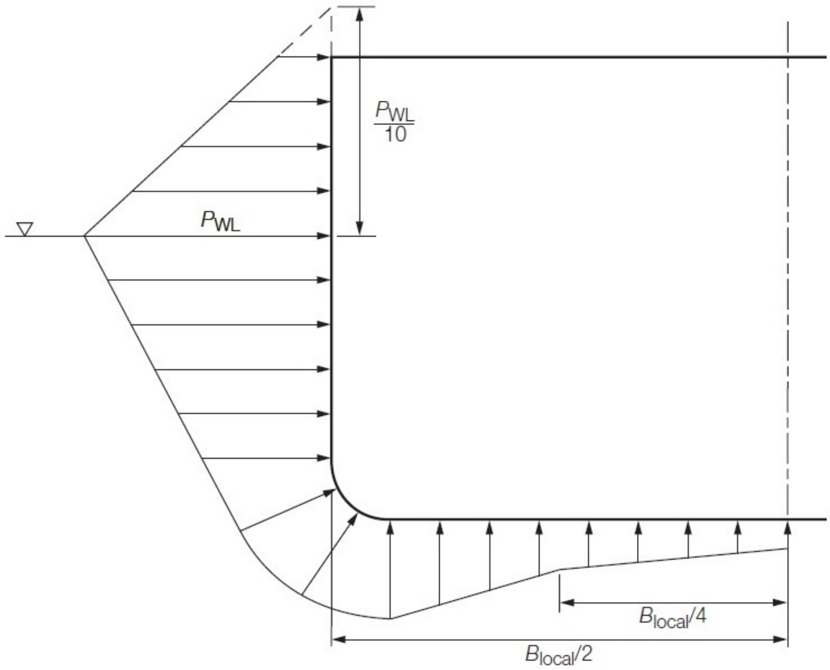


Figure 2.3.4 Transverse distribution of maximum dynamic wave pressure for scantling requirements and strength assessment

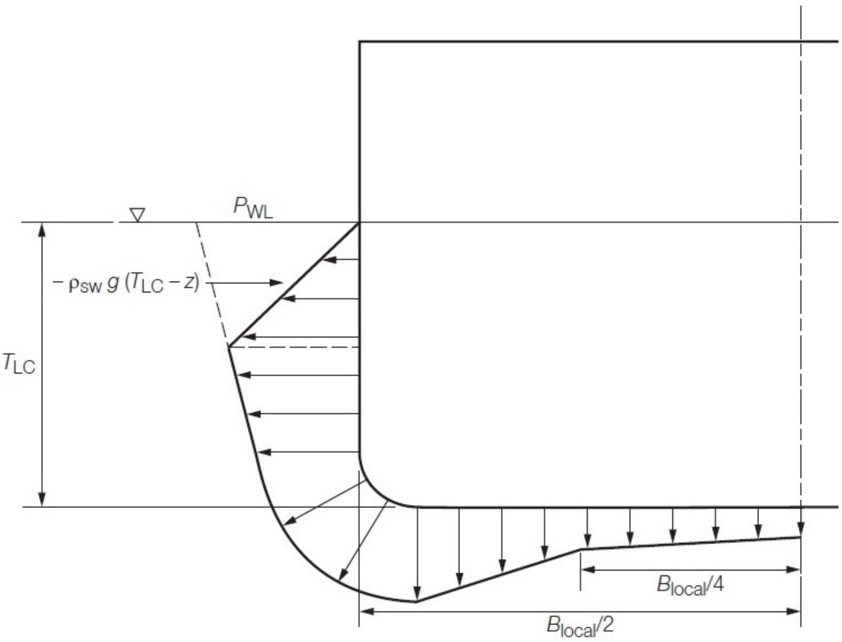


Figure 2.3.5 Transverse distribution of minimum dynamic wave pressure for scantling requirements and strength assessment

Section 4
Sloshing and impact loads

4.1 Sloshing loads

4.1.1 **Application.**

(a) When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the LR ShipRight Procedure for Ship Units. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for cargo bulk storage tanks.

4.2 Bottom slamming loads

4.2.1 **Application and limitations.**

(a) The slamming loads in this Section apply to units with $C_b \geq 0{,}7$ and bottom slamming draught $\geq 0{,}01L$ and $\leq 0{,}045L$. For operation at deeper draughts, the slamming loads will need to be specially considered.

(b) For units with unconventional bow shapes or for harsh service, the slamming loads, green sea loads and bow impact loads are to be determined by a site-specific analysis. The analysis results are to be verified by model tests.

4.2.2 **Slamming pressure.**

(a) The bottom slamming pressure, P_{slm} , is to be taken as the greater of:

$P_{slm-mt} = f_{slm} f_{Env-Pex-dyn}\ 130g\ c_{slm-mt}\, e^{c}{}_{1}$ kN/m^2 for empty tanks

$P_{\text{slm}-\text{full}} = f_{\text{slm}} f_{\text{Env}-\text{Pex}-\text{dyn}}$ $130g$ $c_{\text{slm}-\text{full}} e^{\text{c}}{}_{1} - c_{\text{av}}$ ρ g z_{ball} kN/m^2 for full tanks

where

g = acceleration due to gravity, 9,81 m/s^2

f_{slm} = longitudinal slamming distribution factor, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*

= 0,0 at 0,5*L*

= 1,0 at [0,175 – 0,5 (C_{bl} – 0,7)] *L* from F.P.

= 1,0 at [0,1 – 0,5 (C_{bl} – 0,7)] *L* from F.P.

= 0,5 at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

$f_{\text{Env}-\text{Pex}-\text{dyn}}$ = environmental factor due to dynamic wave pressure. For the initial design of units to be taken as that derived for the light load draught in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*

C_{bl} = block coefficient, C_{b} , as defined in *Pt 10, Ch 2, 3.1 Symbols*, but not to be taken less than 0,7 or greater than 0,8

= slamming coefficient for empty tanks

$C_{\text{slm}-\text{mt}}$ = 5,95 – 10,5 $\left(\frac{T_{\text{FP}-\text{mt}}}{L}\right)^{0,2}$

= slamming coefficient for full tanks

$C_{\text{slm}-\text{full}}$ = 5,95 – 10,5 $\left(\frac{T_{\text{FP}-\text{full}}}{L}\right)^{0,2}$

C_1 = 0,0 for $L \leq 180$ m

= – 0,0125 $(L - 180)^{0,705}$ for $L > 180$ m

$T_{\text{FP}-\text{mt}}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region empty, as defined in *Pt 10, Ch 2, 4.2 Bottom slamming loads 4.2.2*, in metres

$T_{\text{FP}-\text{full}}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region full, as defined in *Pt 10, Ch 2, 4.2 Bottom slamming loads 4.2.2*, in metres

C_{av} = dynamic load coefficient, to be taken as 1,25

L = Rule length, in metres

z_{ball} zball = vertical distance from tank top to load point, in metres.

(b) The designer is to provide the design slamming draughts $T_{\text{FP}-\text{mt}}$ and $T_{\text{FP}-\text{full}}$.

(c) The design slamming draught at the F.P., $T_{\text{FP}-\text{mt}}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for all transit conditions wherein the tanks within the bottom slamming region are empty.

(d) The design slamming draught at the F.P., $T_{\text{FP}-\text{full}}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for any transit conditions wherein the tanks within the bottom slamming region are full.

(e) The loading guidance information is to indicate clearly the design slamming draught.

4.3 Bow impact loads

4.3.1 **Application and limitations.**

(a) The bow impact pressure applies to the side structure in the area forward of 0,1*L* aft of F.P. and between the waterline at draught T_{LT} and the highest deck at side.

4.3.2 Bow impact pressure.

(a) The bow impact pressure, P_{im} , is to be taken as:

$P_{\text{im}} = 1,025 f_{\text{im}} f_{\text{Env − Pex − dyn}} c_{\text{im}} V^{2}_{\text{im}} \sin \gamma_{\text{wl}}$ kN/m2

where

f_{im} = 0,55 at 0,1*L* aft of F.P.

= 0,9 at 0,0125*L* aft of F.P.

= 1,0 at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

$f_{\text{Env − Pex − dyn}}$ = environmental factor due to dynamic wave pressure

For the initial design of units to be taken as:

$f_{\text{Env − Pex − dyn}}$ for the T_{LT} in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6* for the pressure calculation at the light load waterline

$f_{\text{Env − Pex − dyn}}$ for the T_{sc} in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6* for the pressure calculation at and above the deep load waterline

For the pressure calculation in between T_{LT} and T_{sc} , the factor is be obtained by interpolating between the $f_{\text{Env − Pex − dyn}}$ factors for T_{LT} and for T_{sc}

V_{im} = impact speed, in m/s

For fixed locations, impact speed to be taken

as 5 sin $\alpha_{\text{wl}} + \sqrt{L}$

α_{wl} = local waterline angle at the position considered, but is not to be taken as less than 35°, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*

γ_{wl} = local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered, but is not to be less than 50°, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*

c_{im} = 1,0 for positions between draughts T_{LT} and T_{sc}

$= \sqrt{1 + \cos^{2}\left[\frac{90\left(\text{h}_{\text{fb}} - 2\text{h}_{\text{o}}\right)}{\text{h}_{\text{fb}}}\right]}$

for positions above draught T_{sc}

h_{fb} = vertical distance from the waterline at draught T_{sc} to the highest deck at side, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*, in metres

h_{o} = vertical distance from the waterline at draught T_{sc} to the position considered, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*, in metres

L = Rule length, in metres

T_{sc} = scantling draught, in metres

T_{LT} = minimum design light draught, in metres

W_{Lj} = waterline at the position considered, *see Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2*

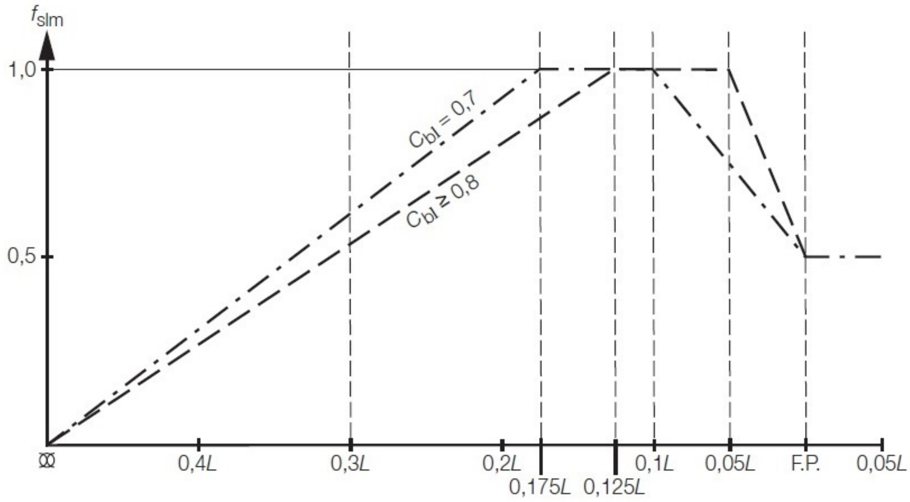


Figure 2.4.1 Longitudinal distribution of slamming pressure

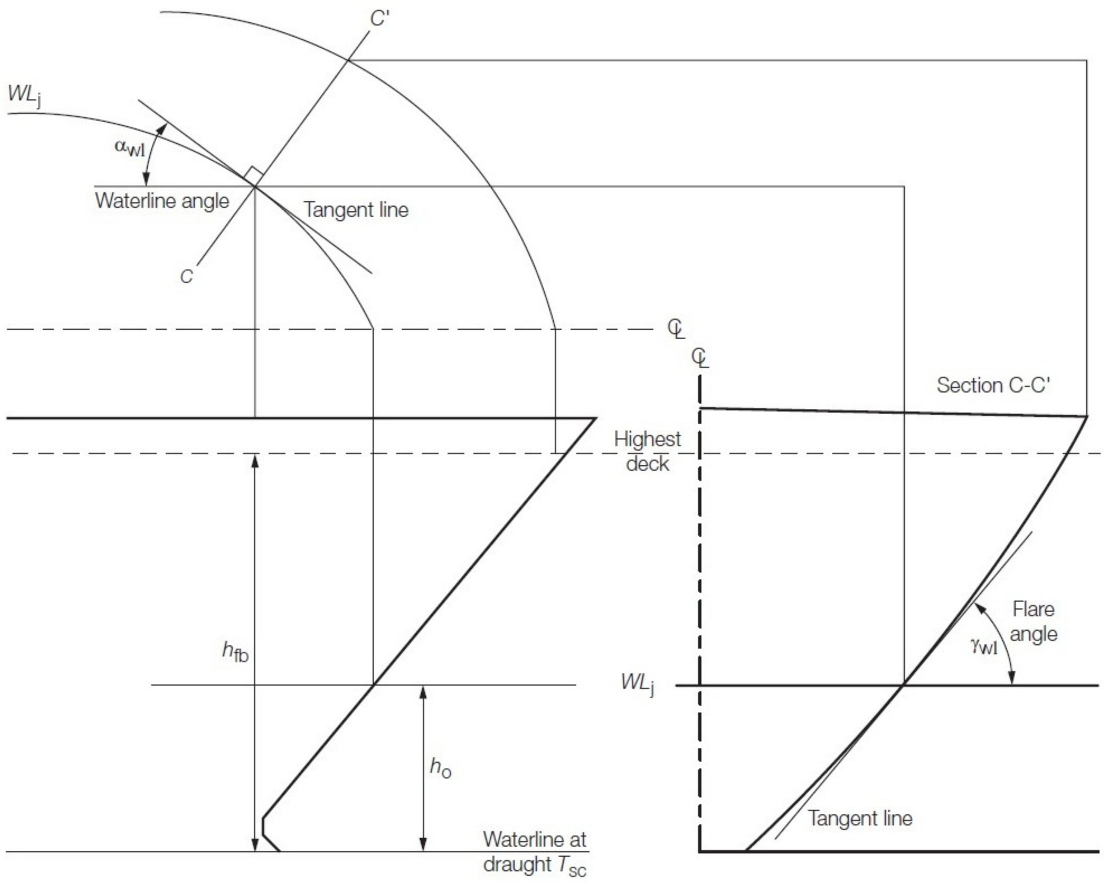


Figure 2.4.2 Definition of bow geometry

■ Section 5
Accidental loads

5.1 Flooded condition

5.1.1 **Global loads.**

(a) The still water bending moments and the still water shear forces in flooded condition are to be determined for each flooding scenario, considering the damaged compartments flooded up to the equilibrium waterline.

5.1.2 **Local pressure.**

(a) The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{\text{in - flood}}$, *see Pt 10, Ch 2, 2.3 Local static loads 2.3.2*.

5.1.3 **Assessment.**

(a) Flooding strength calculations are to be carried out to determine the effects of accidental flooding on the hull strength. Flooding calculations are to be undertaken for all flooding scenarios required by National Regulations. When considering the static and dynamic loads acting simultaneously (S+D), credit may be given to agreed documented mitigation measures where permitted by the National Regulations.

5.2 Blast condition

5.2.1 **Global loads.**

(a) The blast condition is to be assessed for the following load combinations of blast pressure and global loads:

(i) Blast pressure + Permissible still water hogging bending moment for the operational condition.

(ii) Blast pressure + Permissible still water sagging bending moment for the operational condition. Loading conditions where there is no risk of blast loads need not be included in the calculation of the permissible still water bending moments for the blast assessment.

Environmental loads need not be considered. *See also Pt 4, Ch 3, 4.16 Accidental loads*.

5.2.2 **Pressure.**

(a) Generally, the blast pressure is a rapidly propagating pressure or shock-wave in the atmosphere, with high pressure, high density and high particle velocity.

(b) The design blast pressures are to be defined by the Owners/designers and are to comply with National Regulations.

(c) Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods.

5.2.3 **Assessment.**

(a) Assessment of the potential fire loadings and blast pressures are to be based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints. For assessment of the post accident condition, the static loads may be reduced if damage control or recovery measures are implemented, *see Pt 4, Ch 3, 4.3 Load combinations 4.3.1*.

(b) The blast load case is applicable primarily to the upper deck, deck-house and turret boundary. The pressures acting on the opposite side of these structures to the blast load (ballast water pressure, inert gas pressure, etc.) may be ignored when assessing the local scantlings but the hull girder stresses (due to shear and bending) are to be included. The amount of damage to the structure following a blast is to be considered in the assessment.

5.2.4 **Boundary bulkheads and main decks.**

(a) Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and main decks. Where boundary bulkheads and main decks can be subjected to blast loading, the scantlings are to comply with *Pt 4, Ch 3, 4.16 Accidental loads 4.16.9*.

5.3 Collision loads

5.3.1 **General.**

(a) Collision loads are to be considered in the design of the unit as applicable to the function of the unit. In general, the loads described in *Pt 4, Ch 3 Structural Design* are to be considered.

■ *Section 6*
Combination of loads

6.1 Symbols

6.1.1 For the purposes of this Section, the following symbols apply:

$M_{\mathrm{v-total}}$ = design vertical bending moment, in kNm

$M_{\mathrm{sw-perm-maint}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/ maintenance condition, in kNm, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$M_{\mathrm{sw-perm-sea}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$M_{\mathrm{sw-perm-oper}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$M_{\text{sw}-\text{perm}-\text{flood}}$ = permissible hull girder hogging and sagging still water bending moment envelopes for flooded condition, in kNm, *see Pt 10, Ch 2, 6.1 Symbols 6.1.1*

M_{wv} = vertical wave bending moment for a considered dynamic load case, in kNm, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.2*

$M_{\text{h}-\text{total}}$ = design horizontal bending moment, in kNm

M_{h} = horizontal wave bending moment for a considered dynamic load case, in kNm, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.2*

$M_{\text{wv}-\text{hog}}$ = hogging vertical wave bending moment, in kNm, *see Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1*

$M_{\text{wv}-\text{sag}}$ = sagging vertical wave bending moment, in kNm, *see Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1*

$M_{\text{wv}-\text{h}}$ = horizontal wave bending moment, in kNm, *see Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1*

Q = design vertical shear force, in kN

$Q_{\text{sw}-\text{perm}-\text{maint}}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$Q_{\text{sw}-\text{perm}-\text{sea}}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$Q_{\text{sw}-\text{perm}-\text{oper}}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN, *see Pt 10, Ch 2, 2.1 Symbols* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

$Q_{\text{sw}-\text{perm}-\text{flood}}$ = permissible hull girder positive and negative still water shear force envelopes for flood condition, in kN, *see Pt 10, Ch 2, 6.1 Symbols 6.1.1*

Q_{wv} = vertical wave shear force for a considered dynamic load case, in kN, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.2*

$Q_{\text{wv}-\text{pos}}$ = envelope positive vertical wave shear force, in kN, as defined in *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.2*

$Q_{\text{wv}-\text{neg}}$ = envelope negative vertical wave shear force, in kN, as defined in *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.2*

f_{mv} = dynamic load combination factor for vertical wave bending moment for considered dynamic load case, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.2*

f_{qv} = dynamic load combination factor for vertical wave shear force for considered dynamic load case, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.3*

$f\beta$ = heading correction factor, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.1*

P_{ex} = design sea pressure, in kN/m^2

Table 2.6.1 Design load combinations

Global hull girder loads									
Load component		Operation on-site		Inspection/maintenance		Transit		Flooded	
		S	S+D	S	S+D	S	S+D	S	S+D
$M_{\text{v}-\text{total}}$		$M_{\text{sw-perm-oper}}$	$M_{\text{sw-perm-oper}} + M_{\text{wv}}$	$M_{\text{sw-perm-maint}}$	$M_{\text{sw-perm-maint}} + M_{\text{wv}}$	$M_{\text{sw-perm-sea}}$	$M_{\text{sw-perm-sea}} + M_{\text{wv}}$	$M_{\text{sw-perm-flood}}$	$M_{\text{sw-perm-flood}} + M_{\text{wv}}$
$M_{\text{h}-\text{total}}$		–	M_{h}	–	M_{h}	–	M_{h}	–	M_{h}
Q		$Q_{\text{sw-perm-oper}}$	$Q_{\text{sw-perm-oper}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-maint}}$	$Q_{\text{sw-perm-maint}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-sea}}$	$Q_{\text{sw-perm-sea}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-flood}}$	$Q_{\text{sw-perm-flood}} + Q_{\text{wv}}$
Local loads									
Load component	Space type	Operation on-site		Inspection/maintenance		Transit		Flooded	
		S	S+D	S	S+D	S	S+D	S	S+D

External sea pressure	P_{ex}	Exposed deck		$P_{wdk-dyn}$		$P_{wdk-dyn}$		$P_{wdk-dyn}$		$\max\left(P_{hys} + P_{ex-dyn}, P_{wdk-dyn}\right)$
		Hull envelope	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$	P_{hys}	$P_{hys} + P_{wv-dyn}$
Liquid pressure	P_{in}	Ballast tanks	$P_{in-air} + P_{drop}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-test}$	$P_{in-test} + P_{in-dyn}$	$P_{in-air} + P_{drop}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-flood}$	$\max\left(P_{in-tk}, P_{in-flood}\right) + P_{in-dyn}$
		Cargo tanks/ other tanks designed for liquid filling	$P_{in-tk} + P_{valve}$	$P_{in-tk} + P_{in-dyn}$	$\max\left(P_{in-tk} + P_{valve}, P_{in-test}\right)$	$P_{in-test} + P_{in-dyn}$	$P_{in-tk} + P_{valve}$	$P_{in-tk} + P_{in-dyn}$	$P_{in-flood}$	$\max\left(P_{in-tk}, P_{in-flood}\right) + P_{in-dyn}$
		Fresh water and fuel/ lube oil tanks	P_{in-air}	$P_{in-tk} + P_{in-dyn}$	$P_{in-test}$	$P_{in-test} + P_{in-dyn}$	P_{in-air}	$P_{in-tk} + P_{in-dyn}$	$P_{in-flood}$	$\max\left(P_{in-tk}, P_{in-flood}\right) + P_{in-dyn}$
		Water tight boundaries/ void spaces			$P_{in-test}$	$P_{in-test} + P_{in-dyn}$			$P_{in-flood}$	$\max\left(P_{in-tk}, P_{in-flood}\right) + P_{in-dyn}$
		Dry space							$P_{in-flood}$	$P_{in-flood} + P_{in-dyn}$
Deck loads	P_{dk}	Dry space	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$	P_{stat}	$P_{stat} + P_{dk-dyn}$

NOTES

1. All the dynamic wave loads are to be adjusted by the f_{prob} factor. The value of f_{prob} is dependent on the operational condition, *see Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob* .

2. The pressure in cargo tanks, and other tanks designed for liquid filling, that are stated in the unit's Operations Manual as not to be loaded during transit may be taken as zero for the transit assessment.

P_{hys} = static sea pressure at considered draught, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.2*

P_{wv-dyn} = dynamic wave pressure for a considered dynamic load case, in kN/m^2, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

$P_{wdk-dyn}$ = green sea load for a considered dynamic load case, in kN/m^2, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*

P_{in} = design tank pressure, in kN/m^2

$P_{in-test}$ = tank testing pressure, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

$P_{\text{in}-\text{air}}$ = static tank pressure in the case of overfilling, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

P_{drop} = added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3* and *Pt 10, Ch 2, 6.1 Symbols 6.1.1*

P_{valve} = setting of pressure relief valve, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

$P_{\text{in}-\text{tk}}$ = static tank pressure, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

$P_{\text{in}-\text{dyn}}$ = dynamic tank pressure for a considered dynamic load case, in kN/m^2, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*

$P_{\text{in}-\text{flood}}$ = pressure in compartments and tanks in flooded or damaged condition, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

P_{stat} = static pressure on decks and inner bottom, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

P_{dk} = design deck pressure, in kN/m^2, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.3*

$P_{\text{deck}-\text{dyn}}$ = envelope dynamic deck pressure on decks, inner bottom and hatch cover, in kN/m^2, as defined in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.5*

$P_{\text{dk}-\text{dyn}}$ = dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m^2, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7*

P_{ctr} = dynamic wave pressure at bottom centreline, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7*

= $f_{\text{ctr}} P_{\text{ex}-\text{max}}$ kN/m^2

P_{bilge} = dynamic wave pressure at z = 0 and $y = B_{\text{local}}/2$, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7*

= $f_{\text{bilge}} P_{\text{ex}-\text{max}}$ kN/m^2

P_{WL} = dynamic wave pressure at waterline, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7*

= $f_{\text{WL}} P_{\text{ex}-\text{max}}$ kN/m^2

$P_{\text{ex}-\text{max}}$ = envelope maximum dynamic wave pressure, in kN/m^2, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

$P_{1-\text{WL}} = P_1$ pressure at still waterline for considered draught, in kN/m^2, see *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

$P_{2-\text{WL}} = P_2$ pressure at still waterline for considered draught, in kN/m^2, see *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

F_{stat} = load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in *Pt 10, Ch 2, 2.3 Local static loads 2.3.2*

$F_{\text{dk}-\text{dyn}}$ = dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7*

F_{v} = envelope vertical dynamic load from heavy units, in kN, *see Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.6*

f_{WL} = dynamic load combination factor for dynamic wave pressure, P_{WL} , at still waterline for considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

f_{bilge} = dynamic load combination factor for dynamic wave pressure, P_{bilge} , at bilge for considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

f_{ctr} = dynamic load combination factor for dynamic wave pressure, P_{ctr} , at centreline for considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

$f_{1-\text{dk}} = 0{,}8 + \frac{L}{750}$ *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*

$f_{2-\text{dk}} = 0{,}5 + \frac{|y|}{B_{\text{wdk}}}$ *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*

f_{op} = 1,0 at and forward of 0,2L from A.P.

= 0,8 at and aft of A.P.

intermediate values to be obtained by linear interpolation, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*

f_{v} = dynamic load combination factor for vertical acceleration for considered dynamic load case. f_{v} is to be taken as appropriate to the tank location, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*

$f_{\mathrm{v-mid}}$ = dynamic load combination factor for vertical acceleration for considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*

f_{t} = dynamic load combination factor for transverse acceleration for considered dynamic load case, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*

f_{lng} = dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as most appropriate dependent on tank location, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6*

$z_{\mathrm{dk-T}}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*

L = Rule length, in metres

B_{wdk} = local breadth at the weather deck, in metres, see *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

B_{local} = local breadth at waterline for considered draught, in metres, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

T_{LC} = draught in the loading condition being considered, in metres, *see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.4*

x = longitudinal coordinate, in metres

y = transverse coordinate, in metres

z = vertical coordinate, in metres

x_0 = longitudinal coordinate of reference point, in metres

y_0 = transverse coordinate of reference point, in metres

z_0 = vertical coordinate of reference point, in metres

ρ_{sw} = density of sea-water, 1,025 tonnes/m^3

g = acceleration due to gravity, 9,81m/s^2.

6.2 General

6.2.1 Application.

(a) The design load combinations given in *Pt 10, Ch 2, 6.1 Symbols 6.1.1* corresponding to the applicable static load scenarios given in *Pt 10, Ch 2, 2.3 Local static loads* are to be used as the basis for the scantling requirements and strength assessment (by FEM).

(b) For each dynamic load case, the envelope load values as given in *Pt 10, Ch 2, 3 Dynamic load components* are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads.

(c) The procedures for calculating the simultaneously acting dynamic loads are given in *Pt 10, Ch 2, 6.3 Application of dynamic loads*. The dynamic loads for unrestricted worldwide transit are given in *Pt 10, Ch 2, 7 Environmental loads for unrestricted worldwide transit condition*. The dynamic loads for the site-specific load scenarios are given in *Pt 10, Ch 2, 8 Environmental loads for site-specific load scenarios*.

6.3 Application of dynamic loads

6.3.1 Dynamic load combination factors.

(a) For scantling assessment, the dynamic load combination factors used for the calculations of the simultaneously acting dynamic loads are to be taken as given in:

- *Pt 10, Ch 2, 7 Environmental loads for unrestricted worldwide transit condition* for unrestricted worldwide transit;
- *Pt 10, Ch 2, 8 Environmental loads for site-specific load scenarios* for site-specific load scenarios.

For strength assessment by FEM, the dynamic load combination factors are to be taken as given in:

- *Pt 10, Ch 2, 7 Environmental loads for unrestricted worldwide transit condition* for unrestricted worldwide transit;
- *Pt 10, Ch 2, 8 Environmental loads for site-specific load scenarios* for site-specific load scenarios

(b) The heading correction factor, f_{β} , is to be taken as follows:

- For transit conditions using the worldwide environment, as defined in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*:

  f_{β} = 0,8 for beam sea dynamic load cases

  = 1,0 for all other dynamic load cases

- For all other operational conditions, as defined in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6*:

  f_{β} = 1,0 for beam sea dynamic load cases.

6.3.2 **Vertical and Horizontal wave bending moment for a considered dynamic load case.**

(a) The simultaneously acting vertical wave bending moment, M_{wv} and horizontal wave bending moment, M_{h} , are to be taken as:

- Vertical wave bending moment:

  $M_{\mathrm{wv}} = f_{\beta}\, f_{\mathrm{mv}} M_{\mathrm{wv-hog}}$ kNm for $f_{\mathrm{mv}} \geq 0$

  $M_{\mathrm{wv}} = -\, f_{\beta}\, f_{\mathrm{mv}} M_{\mathrm{wv-sag}}$ kNm for $f_{\mathrm{mv}} \geq 0$

- Horizontal wave bending moment:

  $M_{\mathrm{h}} = f_{\beta}\, f_{\mathrm{mh}} M_{\mathrm{wv-h}}$ kNm

6.3.3 **Vertical wave shear force for a considered dynamic load case.**

(a) The simultaneously acting vertical wave shear force, Q_{wv} , is to be taken as:

$Q_{\mathrm{wv}} = f_{\beta}\, f_{\mathrm{qv}} Q_{\mathrm{wv-pos}}$ kNm for $f_{\mathrm{qv}} \geq 0$

$Q_{\mathrm{wv}} = f_{\beta}\, f_{\mathrm{qv}} Q_{\mathrm{wv-neg}}$ kNm for $f_{\mathrm{qv}} < 0$.

6.3.4 **Dynamic wave pressure distribution for a considered dynamic load case.**

(a) The simultaneously acting dynamic wave pressure, $P_{\mathrm{wv-dyn}}$, is to be taken as follows, but not to be less than $-\, r_{sw}\, g\, (T_{\mathrm{LC}} - z)$ below still waterline or less than 0 above still waterline:

- For the port and starboard side within the region with a defined bilge:

  $$P_{\mathrm{wv-dyn}} = P_{\mathrm{ctr}} + \frac{|y|}{0,5B_{\mathrm{local}}}\left(P_{\mathrm{bilge}} - P_{\mathrm{ctr}}\right)$$

  between centreline and start of bilge

  $$P_{\mathrm{wv-dyn}} = P_{\mathrm{ctr}} + \frac{z}{T_{\mathrm{LC}}}\left(P_{\mathrm{WL}} - P_{\mathrm{bilge}}\right)$$

  between end of bilge and still waterline

  $$P_{\mathrm{wv-dyn}} = P_{\mathrm{WL}} - 10\left(z - T_{\mathrm{LC}}\right)$$

  for side shell above still waterline intermediate values of $P_{\mathrm{wv-dyn}}$ around the bilge are to be obtained by linear interpolation along the vertical distance.

- For the port and starboard side within the region without a defined bilge:

  $$P_{\mathrm{wv-dyn}} = P_{\mathrm{ctr}} + \frac{z}{T_{\mathrm{LC}}}\left(P_{\mathrm{WL}} - P_{\mathrm{ctr}}\right)$$

  between bottom centreline and still waterline

  $$P_{\mathrm{wv-dyn}} = P_{\mathrm{WL}} - 10\left(z - T_{\mathrm{LC}}\right)$$

  above still waterline

  where

P_{ctr} = dynamic wave pressure at bottom centreline, to be taken as:

= $f_{\text{ctr}} P_{\text{ex - max}}$ kN/m^2

P_{bilge} = dynamic wave pressure at z = 0 and y = $B_{\text{local}}/2$, to be taken as:

= $f_{\text{bilge}} P_{\text{ex - max}}$ kN/m^2

P_{WL} = dynamic wave pressure at waterline, to be taken as:

= $f_{\text{WL}} P_{\text{ex - max}}$ kN/m^2

(b) *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5* to *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5* illustrate simultaneously acting dynamic wave pressures.

6.3.5 **Green sea load of a considered dynamic load case.**

(a) The simultaneously acting green sea load on the weather deck, $P_{\text{wdk - dyn}}$ is shown in *Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.5*.

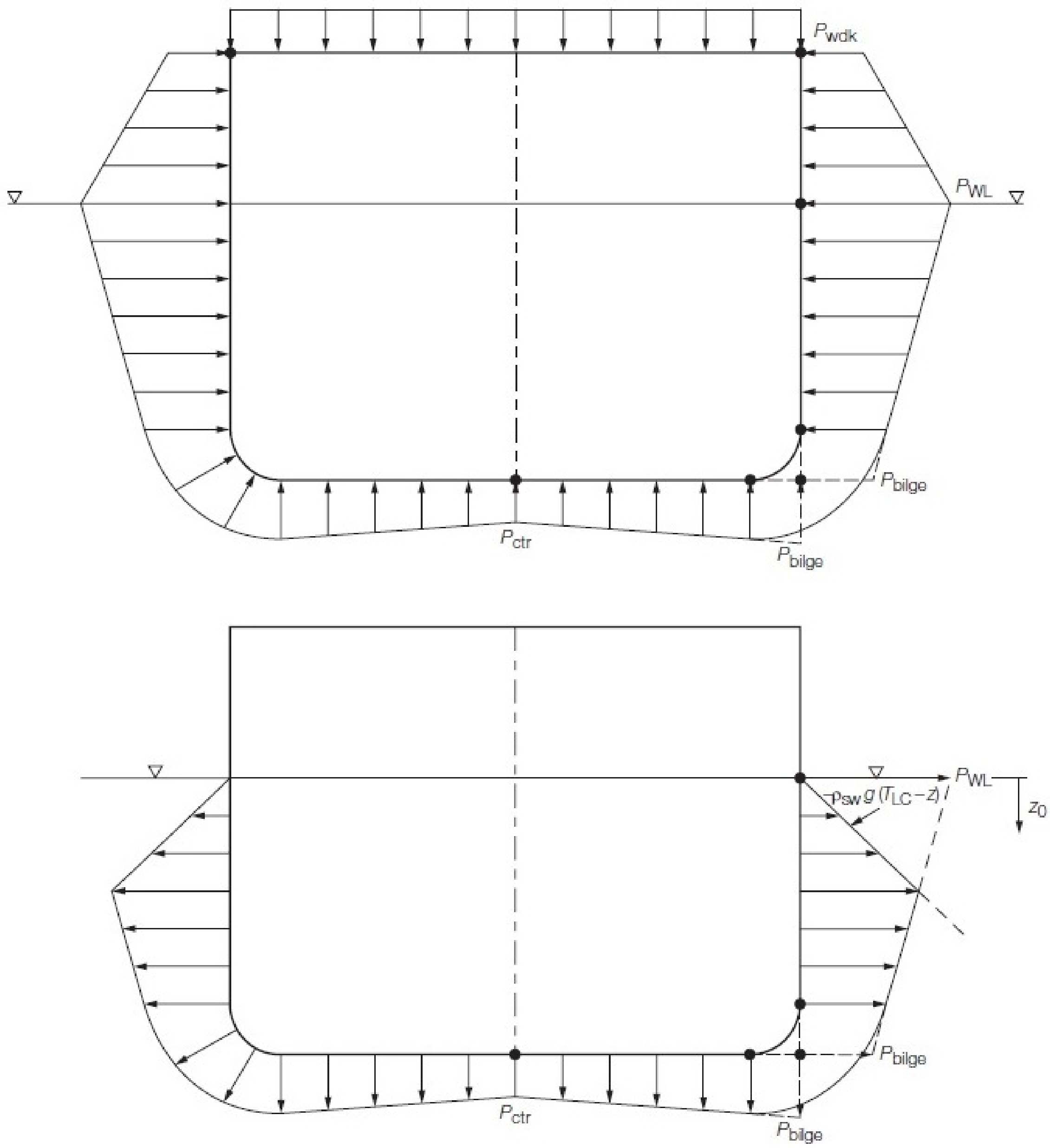


Figure 2.6.1 Dynamic wave pressure for head sea dynamic load cases

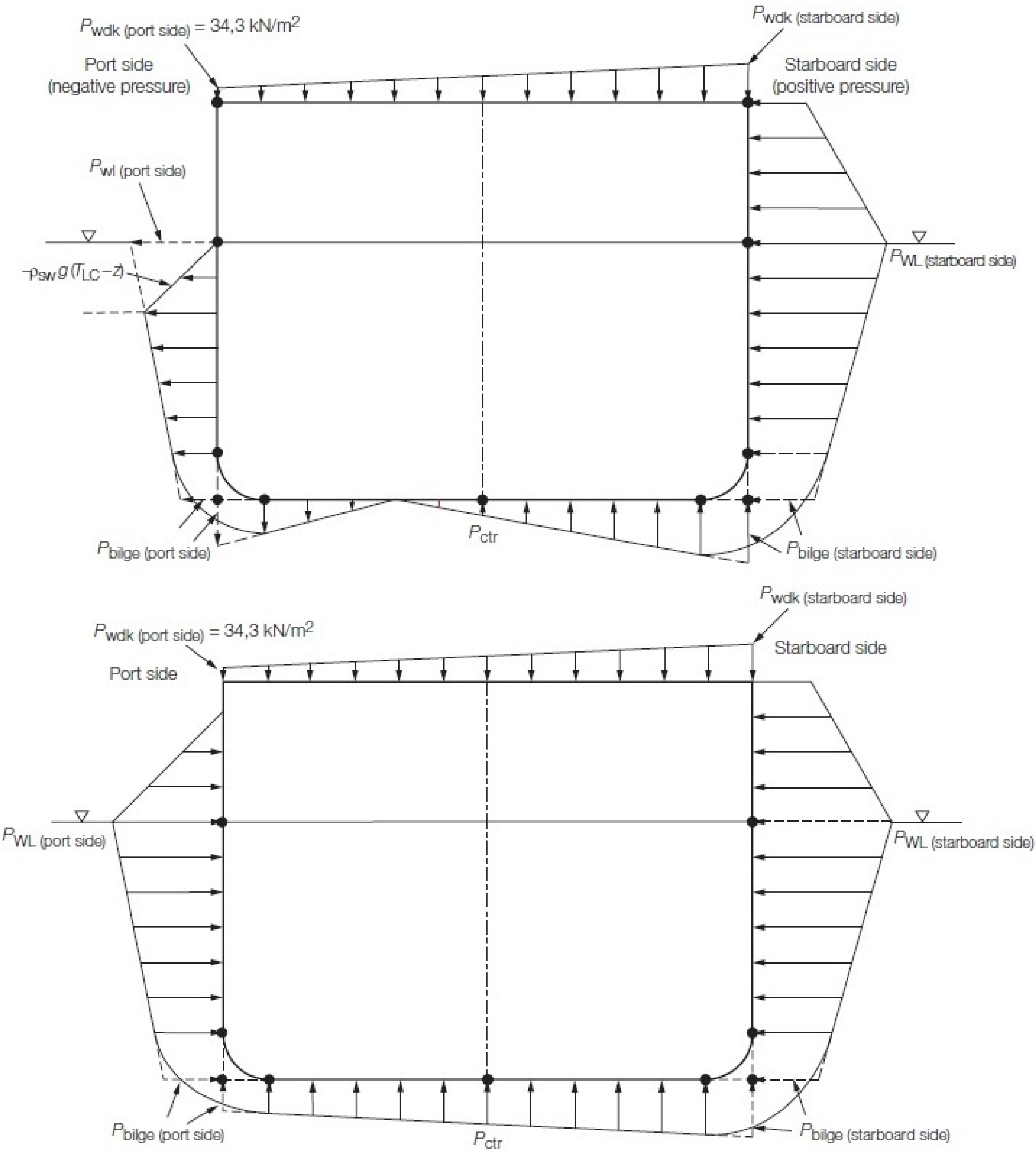


Figure 2.6.2 Dynamic wave pressure for beam sea dynamic load cases

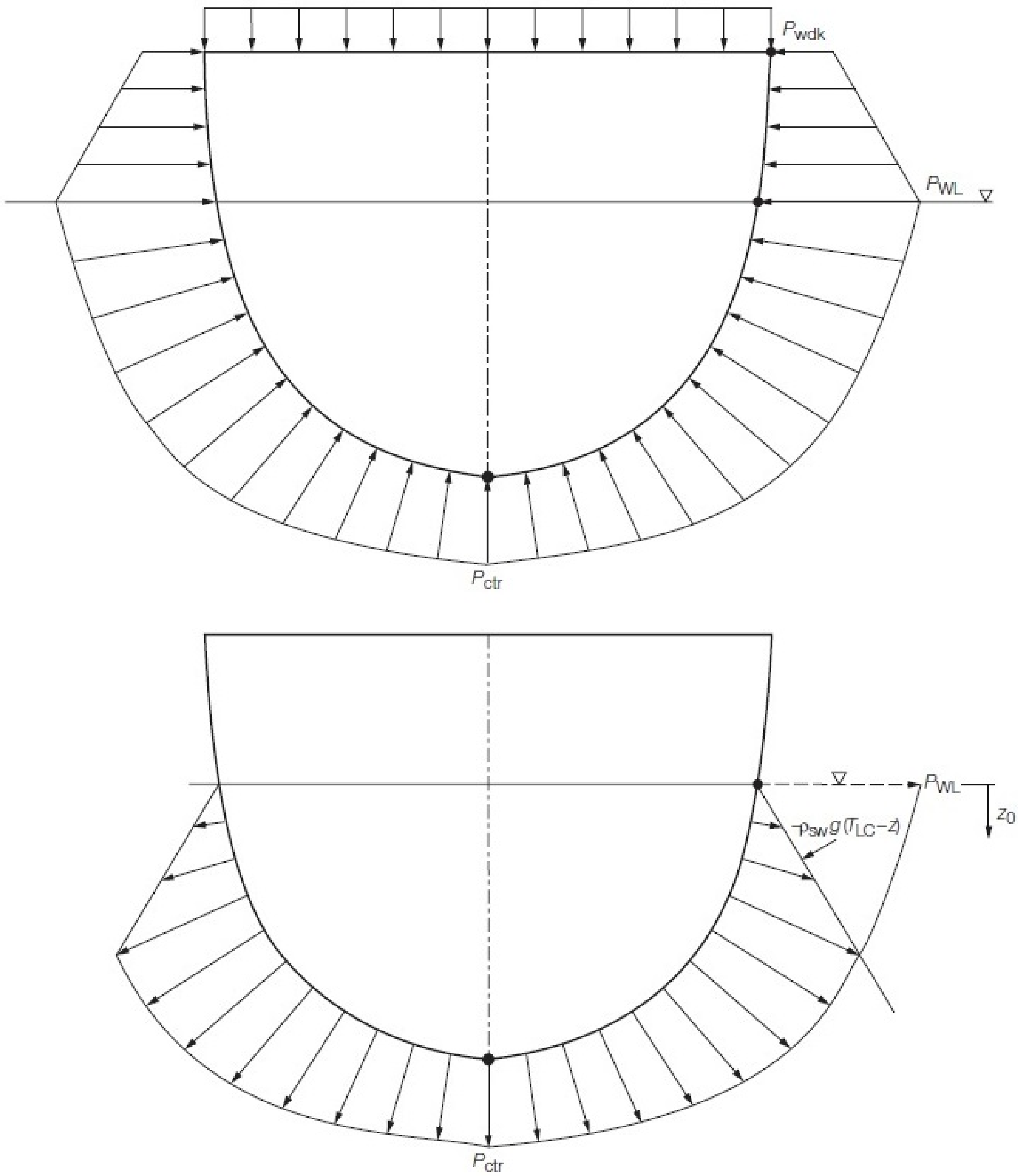


Figure 2.6.3 Pressure distribution for wave crest and wave trough for forward and aft

Table 2.6.2 Green sea load

Inclined green sea load, *see* Note
$P_{\mathrm{wdk-dyn}}$ = max. $\left(f_{1-\mathrm{dk}}\left(f_{\mathrm{WL}}f_{\mathrm{op}}P_{1-\mathrm{WL}}-10z_{\mathrm{dk-T}}\right), 0,8\left(f_{\mathrm{WL}}P_{2-\mathrm{WL}}-10z_{\mathrm{dk-T}}\right), 34,3\right)$ kN/m^2
Uniformly distributed

$P_{\text{wdk}-\text{dyn}}$ = max. $\left(f_{1-\text{dk}}\left(f_{\text{WL}}f_{\text{op}}P_{1-\text{WL}}-10z_{\text{dk}-\text{T}}\right),0,8\left(f_{\text{WL}}P_{2-\text{WL}}-10z_{\text{dk}-\text{T}}\right),34,3\right)$ kN/m^2
NOTE
Inclined green sea load is obtained by linear interpolation between port side and starboard side, with load decreasing from port side to starboard side, with the maximum value at vessel side given by the formula and the minimum value at the opposite side taken as 34,3 kN/m^2. The assessment is then to be repeated, with loading decreasing from starboard side to port side.

6.3.6 **Dynamic tank pressure for a considered dynamic load case.**

(a) The simultaneously acting dynamic tank pressure, $P_{\text{in}-\text{dyn}}$, is to be taken as:

- For tanks in the cargo region:

  $P_{\text{in}-\text{dyn}} = f_{\beta}\left(f_{\text{v}}P_{\text{in}-\text{v}}+f_{\text{t}}P_{\text{in}-\text{t}}+f_{\text{lng}}P_{\text{lng}}\right)$ kN/m^2

- For tanks outside the cargo region:

  $P_{\text{in}-\text{dyn}} = f_{\beta}\left(f_{\text{v}-\text{mid}}P_{\text{in}-\text{v}}+\left|f_{\text{t}}P_{\text{in}-\text{t}}\right|+\left|f_{\text{lng}}P_{\text{lng}}\right|\right)$ kN/m^2

  where

  $P_{\text{in}-\text{v}}$ = envelope dynamic tank pressure due to vertical acceleration, as defined in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.4* with reference point z_0 taken as:

(a) top of tank
(b) top of air pipe/overflow for ballast tanks designed

see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6, in kN/m^2

$P_{\text{in}-\text{t}}$ = envelope dynamic tank pressure due to transverse acceleration, as defined in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.4* with reference point y_0 taken as:

(a) tank top towards port side for $f_{\text{t}} > 0$
(b) tank top towards starboard side for $f_{\text{t}} < 0$

see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.6, in kN/m$_2$

$P_{\text{in}-\text{lng}}$ = envelope dynamic tank pressure due to longitudinal acceleration, as defined in *Pt 10, Ch 2, 3.8 Dynamic local loads 3.8.4* with reference point x_0 taken as:

(a) forward bulkhead for $f_{\text{lng}} > 0$
(b) aft bulkhead of the tank for $f_{\text{lng}} < 0$,

see Pt 10, Ch 2, 6.3 Application of dynamic loads 6.3.7, in kN/m^2

NOTES

1. For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0 . If the longitudinal load combination factor f_{lng} = 0, y_0 should be selected from the bulkhead with the greater breadth.

2. The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

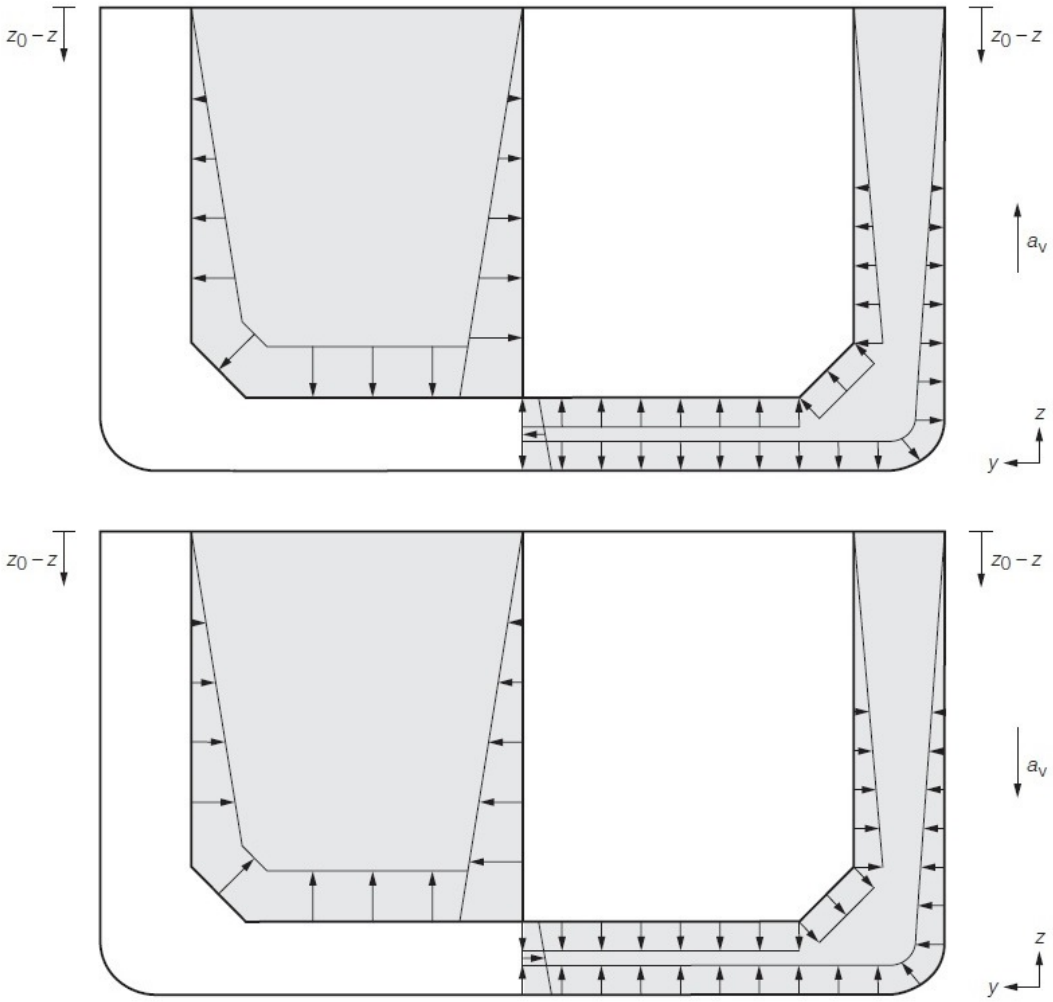


Figure 2.6.4 Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to positive and negative vertical tank acceleration

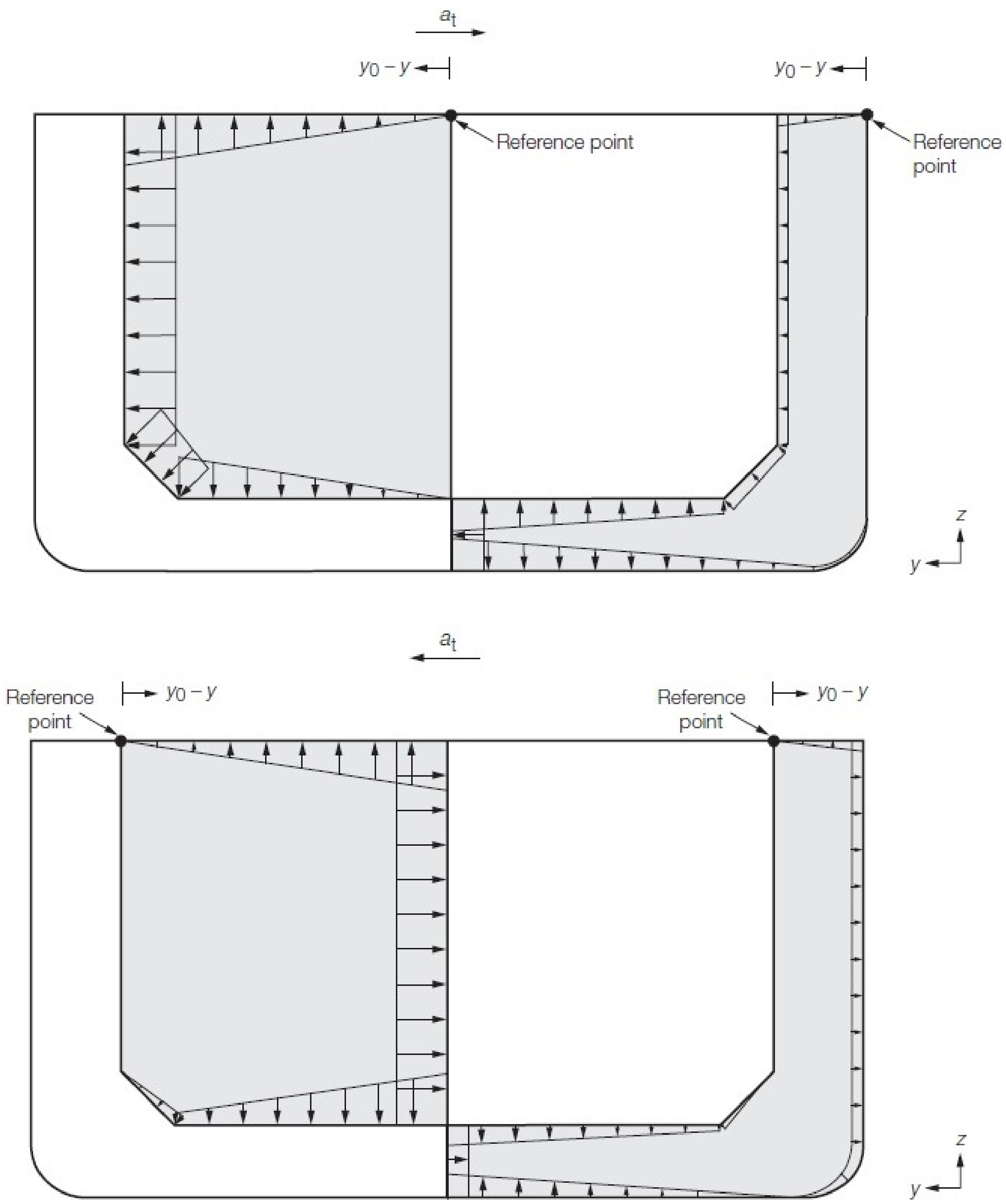


Figure 2.6.5 Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to negative and positive transverse tank acceleration

6.3.7 **Dynamic deck loads for a considered dynamic load case.**

(a) The simultaneously acting dynamic deck load for uniformly distributed load, $P_{\mathrm{dk-dyn}}$, on the enclosed upper deck, where a forecastle or poop is fitted, and also on all lower decks, is to be taken as:

$P_{\mathrm{dk-dyn}} = f_{\beta}\, f_{\mathrm{v-mid}} P_{\mathrm{deck-dyn}}$ kN/m^2

(b) The simultaneously acting dynamic vertical force for heavy units, $F_{\text{dk}-\text{dyn}}$, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$F_{\text{dk}-\text{dyn}} = f_\beta\, f_{\text{v}-\text{mid}} F_\text{v}$ kN

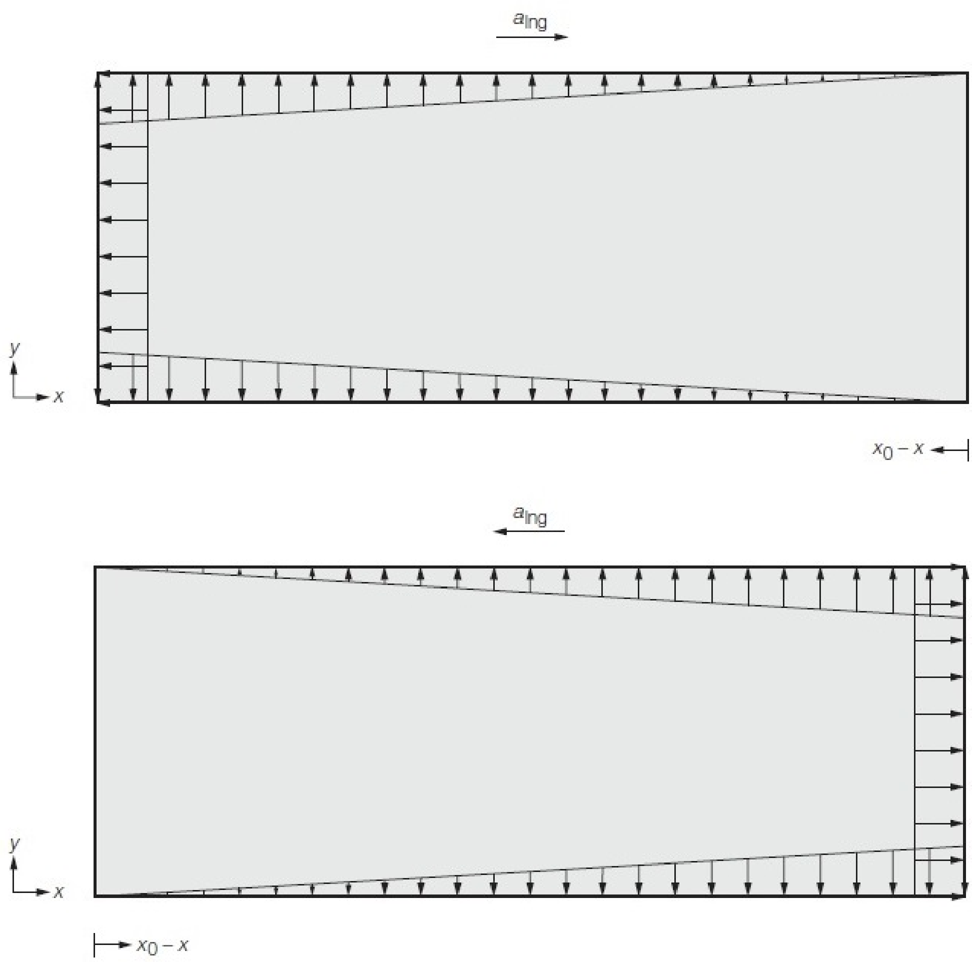


Figure 2.6.6 Dynamic tank pressure in tanks due to positive and negative longitudinal acceleration

■ *Section 7* Environmental loads for unrestricted worldwide transit condition

7.1 Dynamic load cases and dynamic load combination factors for strength assessment

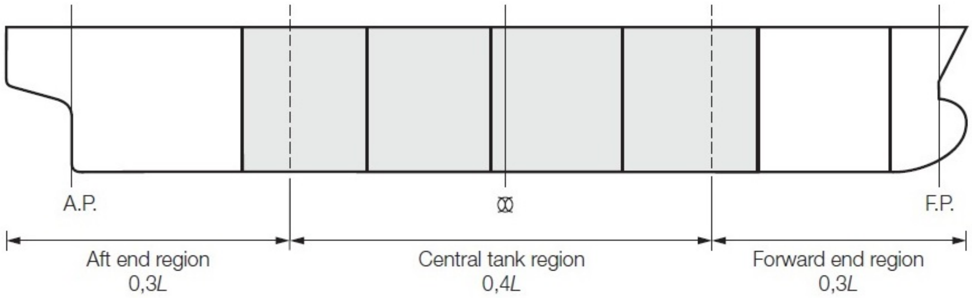
7.1.1 **General.**

(a) For the scantling requirements, the dynamic load cases are to be applied in accordance with the design load sets for the design load combination *S* + *D*. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in *Pt 10, Ch 4 Appendix A Dynamic Load Combination Factors* for unrestricted world wide transit.

(b) The Dynamic Load Combination Factors (DLCF) are dependent on the longitudinal position being considered. Tables are given in *Pt 10, Ch 4 Appendix A Dynamic Load Combination Factors* for the longitudinal positions specified in *Pt 10, Ch 2,*

7.1 Dynamic load cases and dynamic load combination factors for strength assessment 7.1.1, for light load and deep load draughts.

(c) For the strength assessment by FEM, the simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in *Pt 10, Ch 4 Appendix A Dynamic Load Combination Factors* for unrestricted world wide transit.



NOTES
1. Dynamic load cases for the aft region are applicable to tanks and spaces with their longitudinal centre of gravity position aft of 0,3*L* from A.P.
2. Dynamic load cases for the central tank region are applicable to tanks and spaces with their longitudinal centre of gravity position at or forward of 0,3*L* from AP and at or aft of 0,7*L* from A.P.
3. Dynamic load cases for the forward region are applicable to tanks and spaces with their longitudinal centre of gravity position forward of 0,7*L* from A.P.
4. Where the Rule length, *L* is greater than 350 metres, special consideration will be required for the assignment of the structural regions to DLCF tables.

Figure 2.7.1 Illustration of structural regions for DLCF Tables

■ *Section 8* Environmental loads for site-specific load scenarios

8.1 Site-specific dynamic load combination factors

8.1.1 **Application.**

(a) Site-specific dynamic load combination factors (DLCFs) are to be derived from the environmental loads for the proposed area of operation. The simultaneously acting dynamic load cases are to be applied using the site-specific DLCFs.

(b) The operating area notation will be assigned consistent with the geographic area used for the site-specific assessment.

(c) The assessment of environmental loads is to consider *Pt 10, Ch 1, 5.1 General 5.1.3* for new-build units and *Pt 10, Ch 1, 6.1 General 6.1.3* for tanker conversions. *See also Pt 4, Ch 3, 4.1 General*.

(d) Alternative methods of establishing the environmental loads will be specially considered, provided that they are based on hindcast data, long-term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

(e) In order that an assessment of the design requirements can be made, the following information is to be submitted:

- (i) Service area notation required together with the required extent of the operational area.
- (ii) The wave environmental parameters for the design.
- (iii) Specification of the environmental conditions used for the design assessment.

(f) Dynamic Load Combination Factor (DLCF) Tables are specified in Appendix A for the geographic locations shown in *Pt 10, Ch 2, 3.4 Return periods and probability factor, fprob 3.4.6* in *Pt 10, Ch 2 Loads and Load Combinations*. These Tables may be used for the initial design of units operating at these locations. The Tables may be used for on-site operation and

inspection/maintenance load scenarios. The deep draught DLCF Table for the operational condition may be used for the initial design of units for the flooded case.

The DLCF Tables are dependent on the longitudinal position being considered. The Tables given in *Pt 10, Ch 4 Appendix A Dynamic Load Combination Factors* have been derived for the longitudinal positions specified in *Pt 10, Ch 2, 7.1 Dynamic load cases and dynamic load combination factors for strength assessment 7.1.1*, for light load and deep load draughts.

Section

■ *Section 1* Scantling requirements

1.1 Symbols

1.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

B = moulded breadth, in metres, as defined in *Pt 4, Ch 1, 5 Definitions*

D = moulded depth, as defined in *Pt 4, Ch 1, 5 Definitions*

C_{wv} = wave coefficient, as defined in *Pt 10, Ch 2, 3.1 Symbols*

C_{b} = block coefficient, as defined in *Pt 4, Ch 1, 5 Definitions*, but is not to be taken as less than 0,7

ρ = density, tonnes/m^3, not to be taken less than specified values defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.3* in *Pt 10, Ch 2 Loads and Load Combinations*

g = acceleration due to gravity, 9,81 m/s^2

k = higher strength steel factor, as defined in *Pt 10, Ch 1, 3.1 General 3.1.7*.

1.2 Loading guidance

1.2.1 All units are to be provided with loading guidance information containing sufficient information to enable the loading, unloading and ballasting operations and inspection/ maintenance of the unit within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in *Pt 3, Ch 4,8* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2.2 All relevant loading conditions and limitations are to be clearly stated in the loading manual. The loading computer system should be installed to monitor still water bending moments and shear forces and ensure they are maintained within the approved permissible levels.

1.3 Hull girder bending strength

1.3.1 **General.**

(a) The hull girder section modulus requirements in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3* apply along the full length of the hull girder, from AP to FP.

(b) Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in *Pt 10, Ch 3, 1.5 Hull girder buckling strength*.

1.3.2 **Minimum requirements.**

(a) In order to limit the maximum permissible deflection, at the midship the net vertical hull girder section moment of inertia, $I_{\mathrm{v-net50}}$,a about the horizontal neutral axis is not to be less than the following:

$$I_{\mathrm{v-min}} = 2,7C_{\mathrm{wv}}L^3B\left(C_{\mathrm{b}}+0,7\right)10^{-8}\ \mathrm{m}^4$$

where

$I_{\mathrm{v-net50}}$ = net vertical hull girder section moment of inertia, in m^4, to be calculated in accordance with Ch 1,13.4.2.

(b) Additional longitudinal strength and stiffness may be required to take account of the interaction between the hull structure and a liquefied gas cargo containment system if fitted.

1.3.3 **Hull girder requirement on total design bending moment.**

(a) The net vertical hull girder section modulus requirement as defined in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3* is to be assessed for both hogging and sagging conditions.

(b) The hull girder net section modulus, $Z_{\mathrm{v-net50}}$, about the horizontal neutral axis is not to be less than the Rule required section modulus, based on the permissible still water and design wave bending moments as follows:

$$Z_{\mathrm{v-req}} = \frac{\left|M_{\mathrm{sw-perm}}+M_{wv-v}\right|}{\sigma_{\mathrm{perm}}}10^{-3}\ \mathrm{m}^3$$

where

$M_{\mathrm{sw-perm}}$ = permissible hull girder hogging or sagging still water bending moment, in kNm, as given in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3*

$M_{\mathrm{wv-v}}$ = hogging or sagging vertical wave bending moment, in kNm, as given in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3*

σ_{perm} = permissible hull girder bending stress as given in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3*, in N/mm^2

$Z_{\mathrm{v-net50}}$ = vertical hull girder net section modulus, in m^3, to be calculated in accordance with Ch 1,13.4.2.

Table 3.1.1 Loads and corresponding acceptance criteris for hull girder bending assessment

Design load combination	Still water bending moment, $M_{\mathrm{sw-perm}}$	Vertical wave bending moment, $M_{\mathrm{wv-v}}$	Permissible hull girder bending stress, σ_{perm} *see* Note 1	
(S)	$M_{\mathrm{sw-perm}}$	0	143/*k*	within 0,4*L* amidships
			105/*k*	at and forward of 0,9*L* from AP and at and aft of 0,1*L* from AP
(S + D)	$M_{\mathrm{sw-perm}}$	$M_{\mathrm{wv-v}}$	190/*k*	within 0,4*L* amidships
			140/*k*	at and forward of 0,9*L* from AP and at and aft of 0,1*L* from AP
Symbols				
$M_{\mathrm{sw-perm}}$ = permissible hull girder hogging and sagging still water bending moment for Static (S) or Static + Dynamic (S+D) design load combination, as applicable from *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations*, for the load case under consideration, in kNm				

M_{wv-v} = hogging and sagging vertical wave bending moments, in kNm, as defined in *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.1* M_{wv-v} is to be taken as: M_{wv-hog} for assessment with respect to hogging vertical wave bending moment M_{wv-sag} for assessment with respect to sagging vertical wave bending moment	
NOTES 1. σ_{perm} is to be linearly interpolated between values given. 2. For the flooded condition the permissible hull girder bending stress is to be taken as equal to the yield stress.	

1.3.4 **Hull girder section**

(a) The following actual hull girder sectional properties are required to be verified:

- (i) vertical hull girder moment of inertia, about the horizontal axis;
- (ii) hull girder section modulus about the horizontal axis – at deck-at-side;
- (iii) hull girder section modulus about the horizontal axis – at keel;
- (iv) hull girder section modulus about the vertical axis – at side;
- (v) hull girder vertical shear area.

(b) The minimum allowable hull girder section properties are to be calculated with every member at a thickness equal to its required net minimum thickness plus half the applicable corrosion addition given in *Pt 4, Ch 3, 7.3 Corrosion additions*.

1.4 Hull girder shear strength

1.4.1 **General.**

(a) The hull girder shear strength requirements apply along the full length of the hull girder, from AP to FP.

(b) The following requirements are applicable to units with standard structural arrangements as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*. Alternative configurations will be specially considered.

1.4.2 **Assessment of hull girder shear strength.**

(a) The net hull girder shear strength capacity, $Q_{v-net50}$, is not to be less than the required vertical shear force, Q_{v-req}:

$$Q_{v-req} = Q_{sw-perm} + Q_{wv} \text{ kN}$$

where

$Q_{sw-perm}$ = permissible hull girder positive or negative still water shear force as given in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in kN

Q_{wv} = vertical wave positive or negative shear force as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in kN.

(b) The permissible positive and negative still water shear forces, $Q_{sw-perm}$, are to satisfy the following for each loading condition:

$$Q_{sw-perm} \leq Q_{v-net50} - Q_{wv-pos} \text{ kN}$$

for maximum permissible positive shear force

$$Q_{sw-perm} \geq Q_{v-net50} - Q_{wv-neg} \text{ kN}$$

for minimum permissible negative shear force

where

$Q_{v-net50}$ = net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity

$= \dfrac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v}$ kN

$\tau_{ij-perm}$ = permissible hull girder shear stress, τ_{perm}, as given in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in N/mm^2, for plate ij

Q_{wv-pos} = positive vertical wave shear force, in kN, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*

Q_{wv-neg} = negative vertical wave shear force, in kN, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*

$t_{ij-net50}$ = equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc-net50}$ and t_{str-k} as appropriate, *see Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3* and *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

t_{net50} = net thickness of plate, in mm

$= t_{grs} - 0{,}5 t_c$

t_{grs} = gross plate thickness, in mm. For corrugated bulkheads, to be taken as the minimum of t_{w-grs} and t_{f-grs}, in mm

t_{w-grs} = gross thickness of the corrugation web, in mm

t_{f-grs} = gross thickness of the corrugation flange, in mm

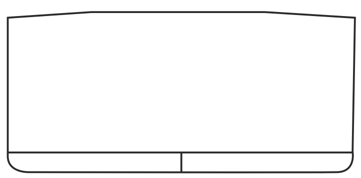
t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*

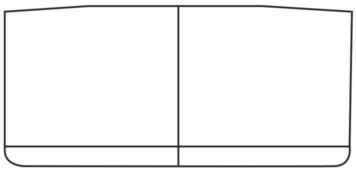
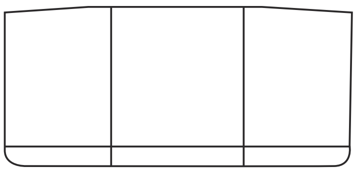
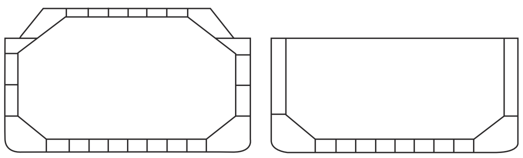
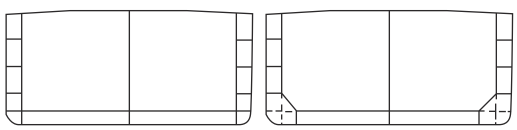
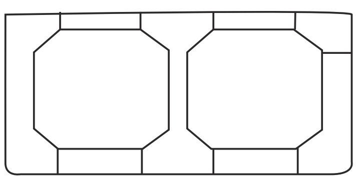
q_v = unit shear flow per mm for the plate being considered and based on the net scantlings. Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to

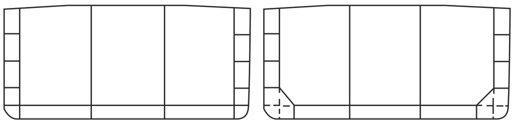
$= f_i \left(\dfrac{q_{1-net50}}{I_{v-net50}} \right) 10^{-9}\ \text{mm}^{-1}$

f_i = shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*.

Table 3.1.2 Shear force distribution factors

Hull configuration	f_i *factors*
Outside cargo region, no longitudinal bulkhead 	*Side shell* $f_1 = 0{,}5$

Outside cargo region, centreline bulkhead 	*Side shell* $f_1 = 0,231 + 0,076\frac{A_{1-net50}}{A_{3-net50}}$ *Longitudinal bulkhead* $f_3 = 0,538 - 0,152\frac{A_{1-net50}}{A_{3-net50}}$
Outside cargo region, two longitudinal bulkheads 	*Side shell* $f_1 = 0,135 + 0,088\frac{A_{1-net50}}{A_{3-net50}}$ *Longitudinal bulkhead* $f_3 = 0,365 - 0,088\frac{A_{1-net50}}{A_{3-net50}}$
Double hull, single cargo tank abreast 	*Side shell* $f_1 = 0,128 + 0,105\frac{A_{1-net50}}{A_{2-net50}}$ *Inner hull* $f_2 = 0,372 - 0,105\frac{A_{1-net50}}{A_{2-net50}}$
Double hull, one centreline bulkhead 	*Side shell* $f_1 = 0,055 + 0,097\frac{A_{1-net50}}{A_{2-net50}} + 0,020\frac{A_{2-net50}}{A_{3-net50}}$ *Inner hull* $f_2 = 0,193 - 0,059\frac{A_{1-net50}}{A_{2-net50}} + 0,058\frac{A_{2-net50}}{A_{3-net50}}$ *Longitudinal bulkhead* $f_3 = 0,504 - 0,076\frac{A_{1-net50}}{A_{2-net50}} - 0,156\frac{A_{2-net50}}{A_{3-net50}}$
Double hull, two centreline bulkheads 	*Side shell* $f_1 = 0,011 + 0,103\frac{A_{1-net50}}{A_{2-net50}} + 0,046\frac{A_{2-net50}}{A_{3-net50}}$ *Inner hull* $f_2 = 0,159 - 0,052\frac{A_{1-net50}}{A_{2-net50}} + 0,054\frac{A_{2-net50}}{A_{3-net50}}$ *Longitudinal bulkhead* $f_3 = 0,330 - 0,051\frac{A_{1-net50}}{A_{2-net50}} - 0,100\frac{A_{2-net50}}{A_{3-net50}}$

Double hull, two longitudinal bulkheads 	*Side shell* $f_1 = 0,028 + 0,087\frac{A_{1-net50}}{A_{2-net50}} + 0,023\frac{A_{2-net50}}{A_{3-net50}}$ *Inner hull* $f_2 = 0,119 - 0,038\frac{A_{1-net50}}{A_{2-net50}} + 0,072\frac{A_{2-net50}}{A_{3-net50}}$ *Longitudinal bulkhead* $f_3 = 0,353 - 0,049\frac{A_{1-net50}}{A_{2-net50}} - 0,095\frac{A_{2-net50}}{A_{3-net50}}$
Symbols	
i =	*index for the structural member under consideration* *1, for the side shell* *2, for the inner hull* *3, for the longitudinal bulkhead*
$A_{i\text{-}net50}$ =	*net area based on deduction 0,5t*$_c$*, of the structural member, i, at one side of the section under consideration. The area* $A_{3\text{-}net50}$ *for the centreline bulkhead is not to be reduced for symmetry around the centreline*

Note *1. The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under, the upper deck girder where applicable, and the longitudinal bulkheads including the double bottom girders in line.*

Note *2. For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane.*

Table 3.1.3 Loads and corresponding acceptance criteria for hull girder shear assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}, *see* Note
(S)	$Q_{sw\text{-}perm}$	0	105/k for plate ij
(S + D)	$Q_{sw\text{-}perm}$	Q_{wv}	120/k for plate ij

Symbols

$Q_{sw\text{-}perm}$ = permissible positive or negative hull girder still water shear force for Static (S) or Static + Dynamic (S + D) design load combination, as applicable from *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations* for the load case under consideration, in kN

Q_{wv} = positive or negative vertical wave shear, in kN, as defined in *Pt 10, Ch 2, 3.7 Dynamic hull girder loads 3.7.2*. Q_{vw} is to be taken as:

$Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force

$Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force

plate ij = for each plate j, index i denotes the structural member of which the plate forms a component

NOTE

For the flooded condition the permissible hull girder shear stress is to be taken as equal to 0,58 yield stress.

$q_{1\text{-}net50}$ = first moment of area, in cm^3, about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50}

$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4 to be calculated in accordance with *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.2 (b)*.

1.4.3 **Shear force correction for longitudinal bulkheads between cargo tanks.**

(a) For longitudinal bulkheads between cargo tanks, the effective net plating thickness of the plating above the inner bottom, $t_{sfc\text{-}net50}$ for plate ij, used for calculation of hull girder shear strength, $Q_{\text{v-net50}}$, may be corrected for local shear distribution and is given by:

$t_{sfc\text{-}net50}$ = $t_{grs} - 0{,}5t_c - t_\Delta$ mm

where

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*

t_Δ = thickness deduction for plate ij, in mm, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*.

(b) The vertical distribution of thickness reduction for shear force correction is assumed to be triangular, as indicated in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*. The thickness deduction, t_Δ, to account for shear force correction is to be taken as:

$$t_\Delta = \frac{\delta_{\text{Q3}}}{h_{\text{blk}}\,\tau_{\text{ij}-\text{perm}}}\left(1-\frac{x_{blk}}{0,5l_{tk}}\right)\left(2-\frac{2\left(z_p-h_{db}\right)}{h_{blk}}\right)\text{ mm}$$

where

δ_{Q3} = shear force correction for longitudinal bulkhead as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3* and *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3* for ship units with one or two longitudinal bulkheads respectively, in kN

l_{tk} = length of cargo tank, in metres

h_{blk} = height of longitudinal bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

x_{blk} = the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in metres. To be taken positive and not greater than $0{,}5l_{tk}$

z_p = the vertical distance from the lower edge of plate ij to the base line, in metres. Not to be taken as less than h_{db}

h_{db} = height of double bottom, in metres, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm}, in N/mm^2 for plate ij

= $120/k_{ij}$

k_{ij} = higher strength steel factor, k, for plate ij as defined in *Pt 10, Ch 3, 1.1 Symbols*.

(c) For ship units with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δ_{Q3}, is to be taken as:

δ_{Q3} = $0{,}5K_3\,F_{db}$ kN

where

K_3 = correction factor, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*.

(d) For ship units with a centreline bulkhead between the cargo tanks, the correction factor, K_3 , in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0,40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads

f_3 = shear force distribution factor, see *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*.

(e) For ship units with two longitudinal bulkheads between the cargo tanks, the shear force correction, δ_{Q3} , is to be taken as:

$$\delta_{Q3} = 0{,}5 K_3 F_{db} \text{ kN}$$

where

K_3 = correction factor, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*.

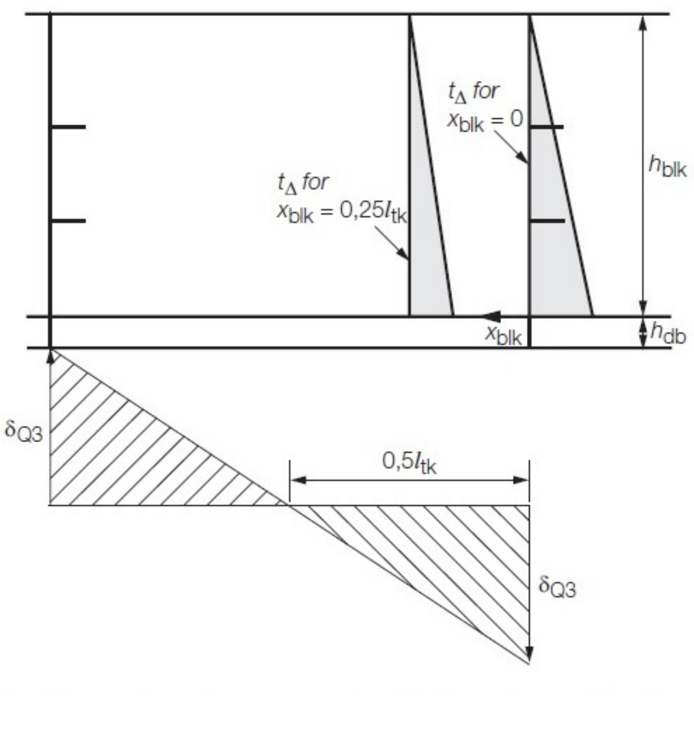


Figure 3.1.1 Shear force correction for longitudinal bulkheads

(f) For ship units with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3 , in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0,5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads

r = ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by

$$r = \frac{1}{\left[\frac{A_{3-net50}}{A_{1-net50} + A_{2-net50}} + \frac{2 \times 10^4 b_{80}(n_s + 1)A_{3-net50}}{l_{tk}(n_s A_{T-net50} + R)}\right]}.$$

NOTE

For preliminary calculations, r may be taken as 0,5

l_{tk} = length of cargo tank, between transverse bulkheads in the side cargo tank, in metres

b_{80} = 80 per cent of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in metres, at tank mid length

$A_{T\text{-}net50}$ = net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T\text{-}net50}$ is to be calculated with net thickness given by t_{grs} – 0,5t_c

$A_{1\text{-}net50}$ = net area, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in m^2

$A_{2\text{-}net50}$ = net area, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in m^2

$A_{3\text{-}net50}$ = net area, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*, in m^2

f_3 = shear force distribution factor, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*

n_5 = number of wash bulkheads in the side cargo tank

R = total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n - n_s}{2} - 1\right)\frac{A_{Q-net50}}{\gamma}\ \text{cm}^2$$

$$\gamma = 1 + \frac{300\, b_{80}{}^2 A_{Q-net50}}{I_{psm-net50}}$$

$A_{Q\text{-}net50}$ = net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs

$A_{Q\text{-}net50}$ is to be calculated using the net thickness given by t_{grs} – 0,5t_c .The net shear area is to be calculated at the midspan of the members

$I_{psm\text{–}net50}$ = net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by t_{grs} – 0,5t_c . The net moment of inertia is to be calculated at the midspan of the member, including an attached plate width equal to the primary support member spacing

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*.

(g) The maximum resulting force on the double bottom in a tank, F_{db} , is to be taken as:

$$F_{db} = g\,|W_{CT} + W_{CWBT} - \rho_{sw}\, b_2\, l_{tk}\, T_{mean}|\ \text{kN}$$

where

W_{CT} = weight of cargo, in tonnes, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

W_{CWBT} = weight of ballast, in tonnes, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

b_2 = breadth, in metres, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*

l_{tk} = length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in metres

T_{mean} = draught at the mid length of the tank for the loading condition considered, in metres.

Table 3.1.4 Design conditions for double bottoms

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ship units with one longitudinal bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast between port and starboard inner sides, in tonnes	Maximum breadth between port and starboard inner sides at mid length of tank, in metres, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*
Ship units with two cargo tanks abreast with a centreline cofferdam	Weight of cargo in cargo tanks, in tonnes, using the specific gravity of the cargo as shown in *Pt 10, Ch 2, 1.2 Definitions 1.2.3* in *Pt 10, Ch 2 Loads and Load Combinations* for strength assessment	Weight of ballast below the cargo tanks, in tonnes	Total breadth of the portion of the ballast tanks below the cargo tanks, in metres as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*
Ship units with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast below the centre cargo tank, in tonnes	Maximum breadth of the centre cargo tank at mid length of tank, in metres, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*
Ship units with a single cargo tank abreast	Weight of cargo in cargo tank, in tonnes, using the specific gravity of the cargo as shown in *Pt 10, Ch 2, 1.2 Definitions 1.2.3* in *Pt 10, Ch 2 Loads and Load Combinations* for strength assessment	Weight of ballast below the cargo tank, in tonnes	Breadth of the ballast tanks below the cargo tank, in metres, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

(h) The maximum resulting force on the double bottom in a tank, F_{db} , is in no case to be less than that given by the Rule minimum conditions given in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3*. Where other tank configurations are proposed, the equivalent loading scenario is to be considered.

Table 3.1.5 Rule minimum conditions for double bottoms

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ship units with one longitudinal bulkhead	Max. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Max. negative net vertical force, F_{db} –	0,6T_{SC} and full cargo tanks and empty ballast tanks
Ship units with two longitudinal bulkheads	Min. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Min. negative net vertical force, F_{db} –	0,6T_{SC} and full centre cargo tank and empty ballast tanks

1.4.4 **Shear force correction due to loads from transverse bulkhead stringers.**

(a) In way of transverse bulkhead stringer connections, within areas as specified in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*, the equivalent net thickness of plate used for calculation of the hull girder shear strength, $t_{str\text{-}k}$, where the index *k* refers to the identification number of the stringer, is not to be taken greater than:

$t_{str\text{-}k}$ = $t_{sfc-net50}\left(1-\dfrac{\tau_{str}}{\tau_{ij-perm}}\right)$ mm

where

$t_{sfc\text{-}net50}$ = effective net plating thickness, in mm, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.3* and calculated at the transverse bulkhead for the height corresponding to the level of the stringer

$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm} , for plate ij

= $120/k_{ij}$ N/mm^2

k_{ij} = higher strength steel factor, *k*, for plate ij, as defined in *Pt 10, Ch 3, 1.1 Symbols*

τ_{str} = $\dfrac{Q_{str-k}}{l_{str}t_{stc-net50}}$ N/mm^2

l_{str} = connection length of stringer, in metres, *see Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

$Q_{str\text{-}k}$ = shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full

= $0,8F_{str-k}\left(1-\dfrac{z_{str}-h_{db}}{h_{bhd}}\right)$ kN

$F_{str\text{-}k}$ = total stringer supporting force, in kN, as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

h_{db} = the double bottom height, in metres, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

h_{blk} = height of bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*

z_{str} = the vertical distance from baseline to the considered stringer, in metres.

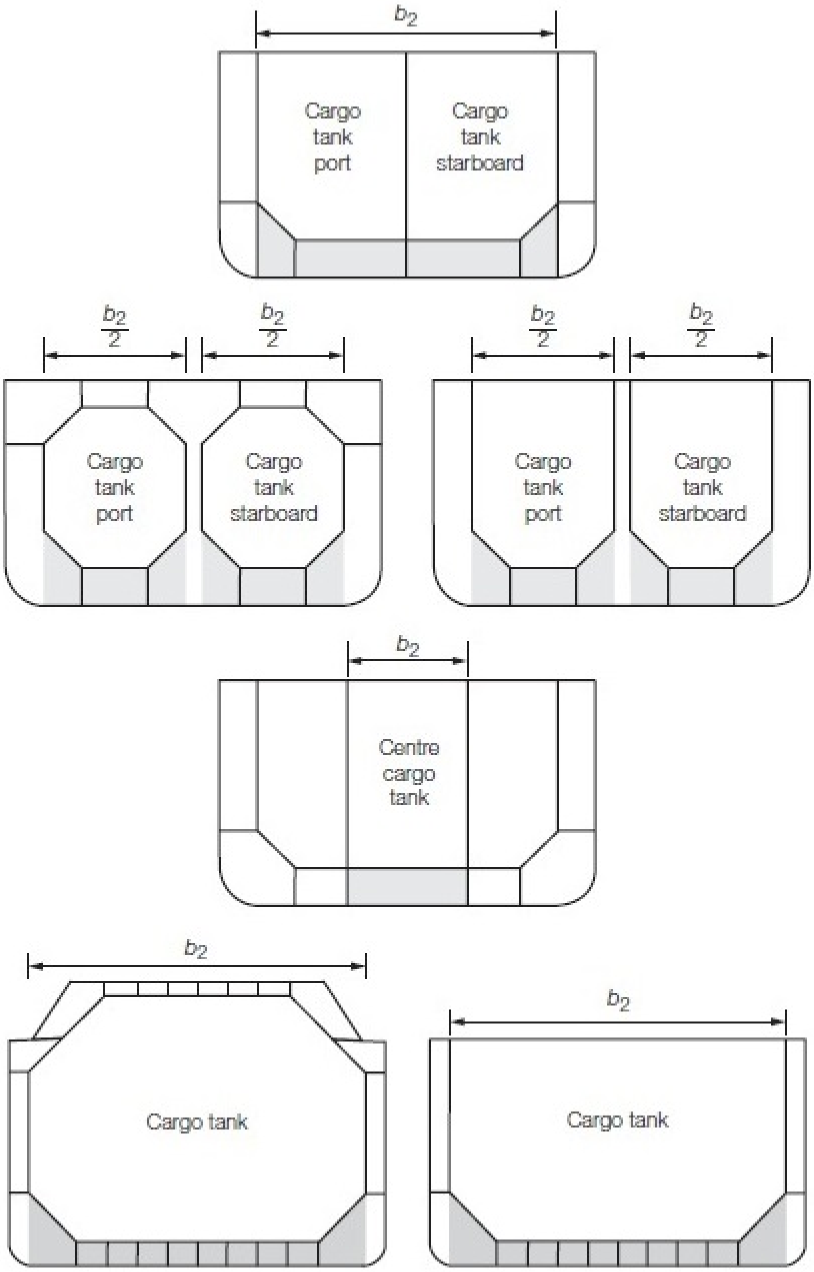


Figure 3.1.2 Tank breadth to be included for standard tank configuration

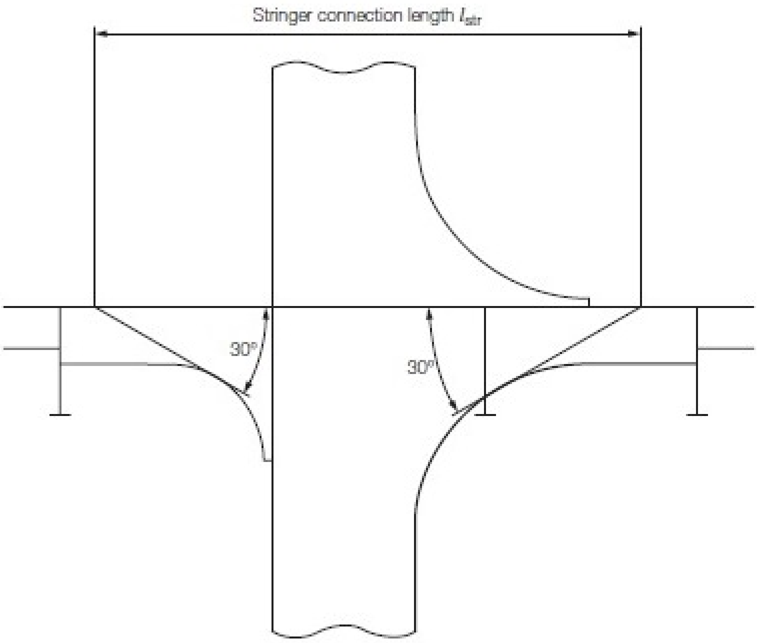


Figure 3.1.3 Effective connection length of stringer

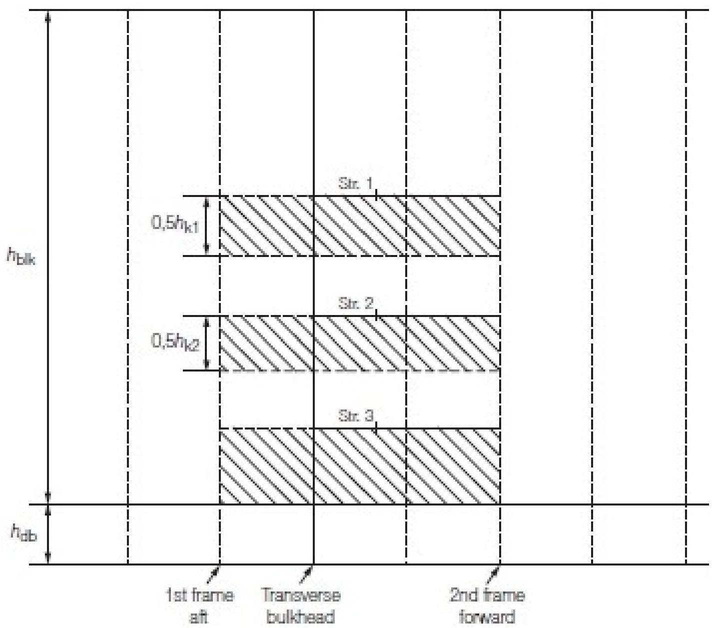


Figure 3.1.4 Region for stringer correction, tij, for a unit with three stringers

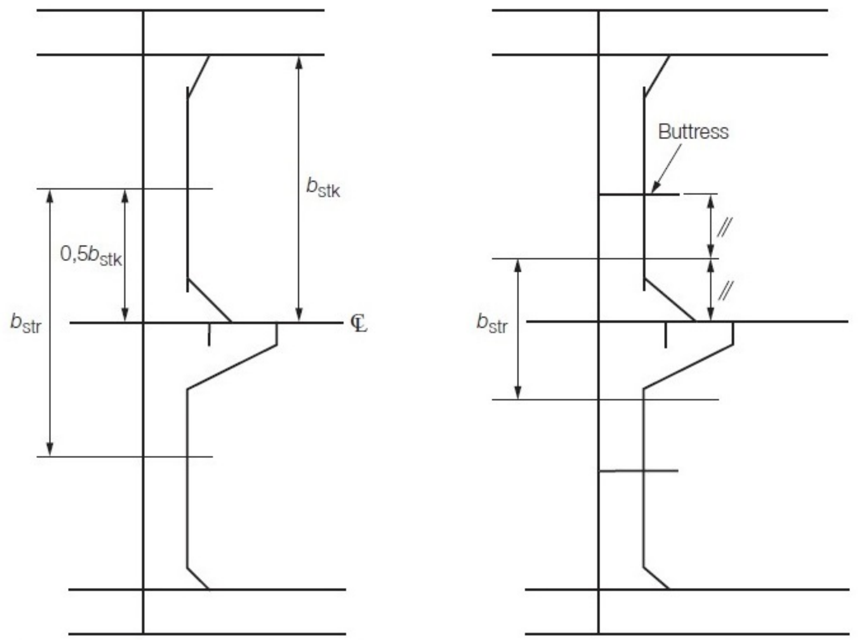


Figure 3.1.5 Load breadth of stringers for units with a centreline bulkhead

(b) The total stringer supporting force, $F_{str\text{-}k}$, in way of a longitudinal bulkhead is to be taken as:

$$F_{str\text{-}k} = \frac{P_{str} b_{str} \left(h_k + h_{k-1} \right)}{2}$$

where

P_{str} = pressure on stringer, in kN/m^2, to be taken as $10h_{tt}$

h_{tt} = the height from the top of the tank to the midpoint of the load area between h_k /2 below the stringer and h_{k-1} /2 above the stringer, in metres

h_k = the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 per cent of the average vertical distance to the inner bottom, in metres

h_{k-1} = the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 per cent of the average vertical distance to the upper deck, in metres

b_{str} = load breadth acting on the stringer, in metres, see *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4* and *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*.

(c) Where reinforcement is provided to meet the above requirement, the reinforced area based on $t_{str\text{-}k}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to $0,5h_k$ below the stringer, where h_k , the vertical distance from the considered stringer to the stringer below, is as defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*. For the lowermost stringer, the plate thickness requirement$t_{str\text{-}k}$ is to extend down to the inner bottom, see*Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.4*.

1.5 Hull girder buckling strength

1.5.1 **General.**

(a) These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for wave bending moments and shear forces given in *Pt 10, Ch 2, 2.2 Static hull girder loads* and *Pt 10, Ch 2, 3.7 Dynamic hull girder loads*.

(b) The hull girder buckling strength requirements apply along the full length of the ship unit, from AP to FP.

(c) For the purposes of assessing the hull girder buckling strength in this sub-Section, the following are to be considered separately:

(i) Axial hull girder compressive stress to satisfy requirements in *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2* and *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*.

(ii) Hull girder shear stress to satisfy requirements in *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*.

1.5.2 **Buckling assessment.**

(a) The buckling assessment of plate panels and longitudinals is to be determined according to *Pt 10, Ch 1, 18 Buckling*, with hull girder stresses calculated on net hull girder sectional properties.

(b) The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net} , as follows:

$$t_{net} = t_{grs} - 1{,}0 t_c \text{ mm}$$

where

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*.

(c) The hull girder compressive stress due to bending, $\sigma_{hg\text{-}net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg\text{-}net50} = \left|\frac{(z - z_{NA-net50})(M_{sw-perm} + M_{wv-v})}{I_{v-net50}}\right| 10^{-3} \text{ N/mm}^2$$

$$\sigma_{hg\text{-}net50} = \frac{30}{k} \text{ N/mm}^2$$

where

$M_{sw\text{-}perm}$ = permissible still water bending moment for the Static + Dynamic (S+D) design load combination, as applicable from *Pt 10, Ch 2, 6.1 Symbols 6.1.1* for the load case under consideration, in kNm, with signs as given in *Pt 10, Ch 2, 1.2 Definitions 1.2.2*

$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in *Pt 10, Ch 2 Loads and Load Combinations*, with signs as given in *Pt 10, Ch 2, 1.2 Definitions 1.2.2*

$M_{wv\text{-}v}$ is to be taken as:

$M_{wv\text{-}hog}$ for assessment with the hogging still water bending moment

$M_{wv\text{-}sag}$ for assessment with the sagging still water bending moment

z = distance from the structural member under consideration to the baseline, in metres

$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4.

(d) The sagging bending moment values of $M_{sw\text{-}perm}$ and $M_{wv\text{-}v}$, are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

(e) The design hull girder shear stress for the buckling assessment, τhg-net50, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg\text{-}net50} = \left|\left(Q_{sw-perm} + Q_{wv}\right)\left(\frac{1000 q_v}{t_{ij-net50}}\right)\right| \text{ N/mm}^2$$

where

$Q_{sw\text{-}perm}$ = positive and negative still water permissible shear force for Static + Dynamic (S+D) design load combination, as applicable from *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations* for the load case under consideration, in kN

Q_{wv} = positive or negative vertical wave shear, in kN, as defined in *Pt 10, Ch 2 Loads and Load Combinations*

Q_{wv} is to be taken as:

$Q_{wv\text{-}pos}$ for assessment with the positive permissible still water shear force

$Q_{wv\text{-}neg}$ for assessment with the negative permissible still water shear force

$t_{ij\text{-}net50}$ = net thickness for the plate ij, in mm

= $t_{ij\text{-}grs} - 0{,}5t_c$

$t_{ij\text{-}grs}$ = gross plate thickness of plate ij, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm

$t_{w\text{-}grs}$ = gross thickness of the corrugation web, in mm

$t_{f\text{-}grs}$ = gross thickness of the corrugation flange, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*

q_v = unit shear per mm for the plate being considered, defined in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*

NOTES

1. Maximum of the positive shear (still water + vertical wave) and negative shear (still water + vertical wave) is to be used as the basis for calculation of design shear stress.

2. All plate elements ij that contribute to the hull girder shear capacity are to be assessed. *See also Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2* and *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2*.

(f) The compressive buckling strength of plate panels is to satisfy the following criteria:

$\eta \geq \eta_{allow}$

where

η = buckling utilisation factor

$$= \frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

$\sigma_{hg\text{-}net50}$ = hull girder compressive stress based on net hull girder sectional properties, in N/mm^2, as defined in *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*

σ_{cr} = critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm^2, as specified in *Pt 10, Ch 1, 18.2 Buckling of plates 18.2.1*. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_c$ as described in *Pt 10, Ch 1, 12 Corrosion additions* is to be used for the calculation of σ_{cr}

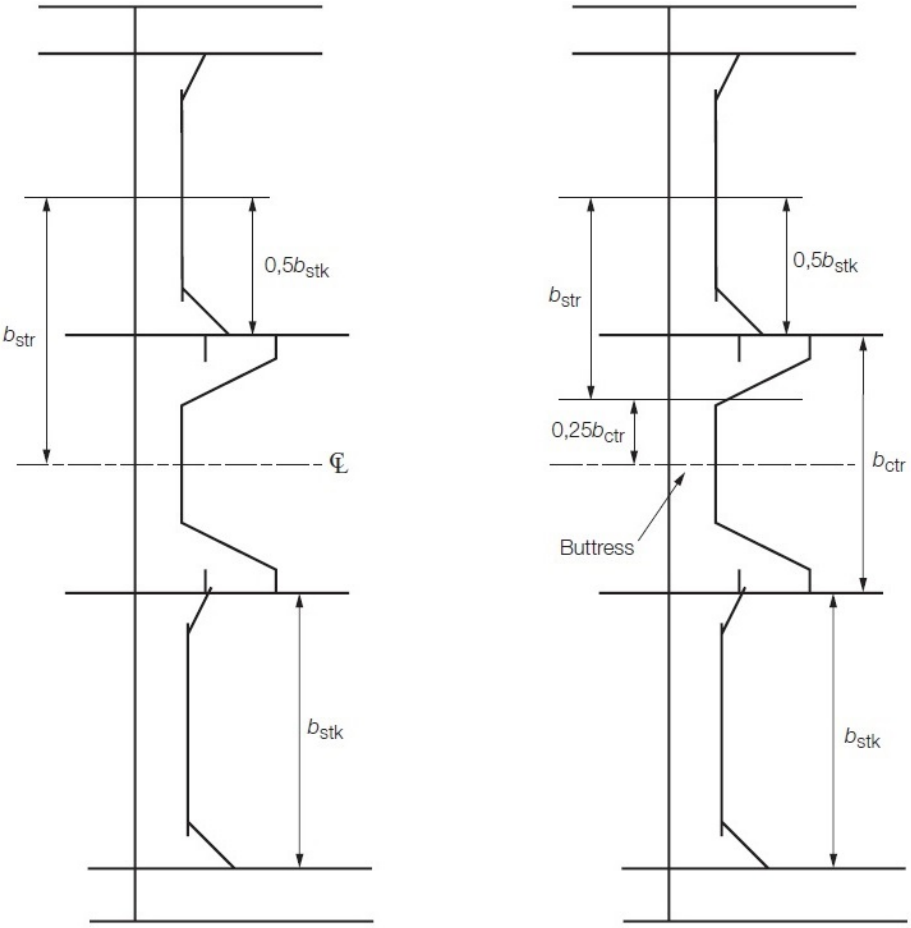
η_{allow} = allowable buckling utilisation factor

= 1,0 for plate panels at or above 0,5*D*

= 0,90 for plate panels below 0,5*D*

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*.



NOTES
1. b_{stk} is the breadth of wing cargo tank, in metres.
2. b_{ctr} is the breadth of centre cargo tank, in metres.

Figure 3.1.6 Load breadth of stringers for units with two inner longitudinal bulkheads

(g) The shear buckling strength of plate panels, is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = buckling utilisation factor

$$= \frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{hg\text{-}net50}$ = design hull girder shear stress, in N/mm^2, as defined in *Pt 10, Ch 3, 1.5 Hull girder buckling strength 1.5.2*

τ_{cr} = critical shear buckling stress, in N/mm^2, specified in *Pt 10, Ch 1, 18.2 Buckling of plates 18.2.1*. The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects

of other membrane stresses and lateral pressure are to be ignored. The net thickness $t_{grs} - t_c$ as described in *Pt 10, Ch 1, 12 Corrosion additions* is to be used for the calculation of τ_{cr}

η_{allow} = allowable buckling utilisation factor

= 0,95

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in *Pt 10, Ch 1, 12 Corrosion additions*.

(h) The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = the greater of the buckling utilisation factors given in *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.2* and *Pt 10, Ch 1, 18.3 Buckling of stiffeners 18.3.3*. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored

η_{allow} = allowable buckling utilisation factor

= 1,0 for stiffeners at or above 0,5*D*

= 0,90 for stiffeners below 0,5*D*.

1.6 Tapering and structural continuity of longitudinal hull girder elements

1.6.1 Tapering based on minimum hull girder section property requirements.

(a) Scantlings required by the Rule minimum moment of inertia and section modulus may be gradually reduced to the local requirements at the ends, provided the hull girder bending and buckling requirements, as given in *Pt 10, Ch 3, 1.3 Hull girder bending strength 1.3.3* and *Pt 10, Ch 3, 1.5 Hull girder buckling strength*, are complied with along the full length of the ship unit.

1.6.2 Longitudinal extent of higher strength steel.

(a) Where used, the application of higher strength steel is to be continuous over the length of the ship unit up to locations where the longitudinal stress levels are within the allowable range for mild steel structure.

1.6.3 Vertical extent of higher strength steel.

(a) The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, see also *Pt 10, Ch 3, 1.6 Tapering and structural continuity of longitudinal hull girder elements 1.6.3*.

$$z_{hts} = z_1\left(1 - \frac{190}{\sigma_1 k_1}\right)$$

where

z_1 = distance from horizontal neutral axis to moulded deck line or keel respectively, in metres

σ_1 = to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm²

σ_{dk} = hull girder bending stress at moulded deck line given by

$$\frac{\left|M_{sw-perm} + M_{wv-v}\right|}{I_{v-net50}}\left(z_{dk-side} - z_{NA-net50}\right)10^{-3} \text{ N/mm}^2$$

σ_{kl} = hull girder bending stress at keel given by

$$\frac{\left|M_{sw-perm} + M_{wv-v}\right|}{I_{v-net50}}\left(z_{NA-net50} - z_{kl}\right)10^{-3} \text{ N/mm}^2$$

$M_{sw\text{-}perm}$ = permissible hull girder still water bending moment for applicable static + dynamic condition, in kNm, as defined in *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations*

$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in *Pt 10, Ch 2, 1.2 Definitions 1.2.2*. Mwv-v is to be taken as:

$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment

$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, in m^4

$z_{dk\text{-}side}$ = distance from baseline to moulded deck line at side, in metres

z_{kl} = vertical distance from the baseline to the keel, in metres

$z_{NA\text{-}net50}$ = distance from baseline to horizontal neutral axis, in metres

k_i = higher strength steel factor for the area *i* defined in *Pt 10, Ch 3, 1.6 Tapering and structural continuity of longitudinal hull girder elements 1.6.3* The factor, *k*, is defined in *Pt 10, Ch 3, 1.1 Symbols*.

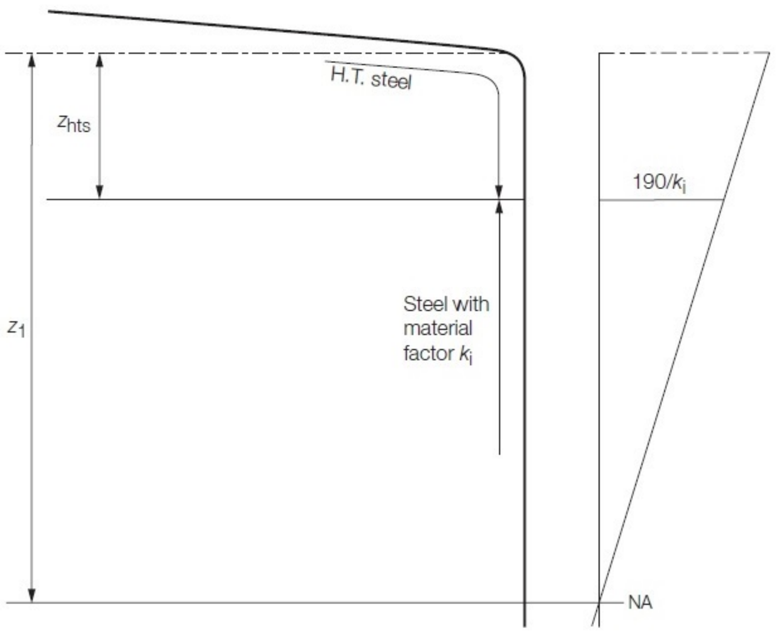


Figure 3.1.7 Vertical extent of higher strength steel

1.6.4 **Tapering of plate thickness due to hull girder shear requirement.**

(a) Longitudinal tapering of shear reinforcement is permitted, provided that the requirements given in *Pt 10, Ch 3, 1.4 Hull girder shear strength 1.4.2* are complied with for any longitudinal position.

1.6.5 **Structural continuity of longitudinal bulkheads.**

(a) Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular, longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 **Structural continuity of longitudinal stiffeners.**

(a) Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.
(b) Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft ends of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel is to be considered.

1.7 Standard construction details

1.7.1 Details to be submitted:

(a) A booklet of standard construction details is to be submitted for review. It is to include the following:
  (i) the proportions of built-up members to demonstrate compliance with established standards for structural stability.
  (ii) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue, such as:

- details of the ends, at the intersections of members and associated brackets;
- shape and location of air, drainage, and/or lightening holes;
- shape and reinforcement of slots or cut-outs for internals;
- elimination or closing of weld scallops in way of butts, 'softening' of bracket toes, reduction of abrupt changes of section or structural discontinuities;
- proportion and thickness of structural members to reduce fatigue response due to machinery operational and/or wave induced cyclic stresses, particularly for higher strength steels.

1.8 Termination of local support members

1.8.1 **General.**

(a) In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.
(b) Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.
(c) All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3* to *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.5*.

1.8.2 **Longitudinal members.**

(a) All longitudinals are to be kept continuous within the 0,4L amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding are to be specially considered.
(b) Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

1.8.3 **Bracketed connections.**

(a) At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings, sufficient to compensate for the non-continuous stiffener flange or noncontinuous stiffener.
(b) The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section modulus less than that required for the stiffener.
(c) Minimum net bracket thickness, $t_{\text{bkt-net}}$, is to be taken as:

$t_{bkt\text{-}net}$ = $\left(2 + f_{bkt} Z_{r1-net}\right)\left(\sqrt{\dfrac{\sigma_{yd-stf}}{\sigma_{yd-bkt}}}\right)$ mm

but is not to be less than 6 mm and need not be greater than 13,5 mm

where:

f_{bkt} = 0,2 for brackets with flange or edge stiffener

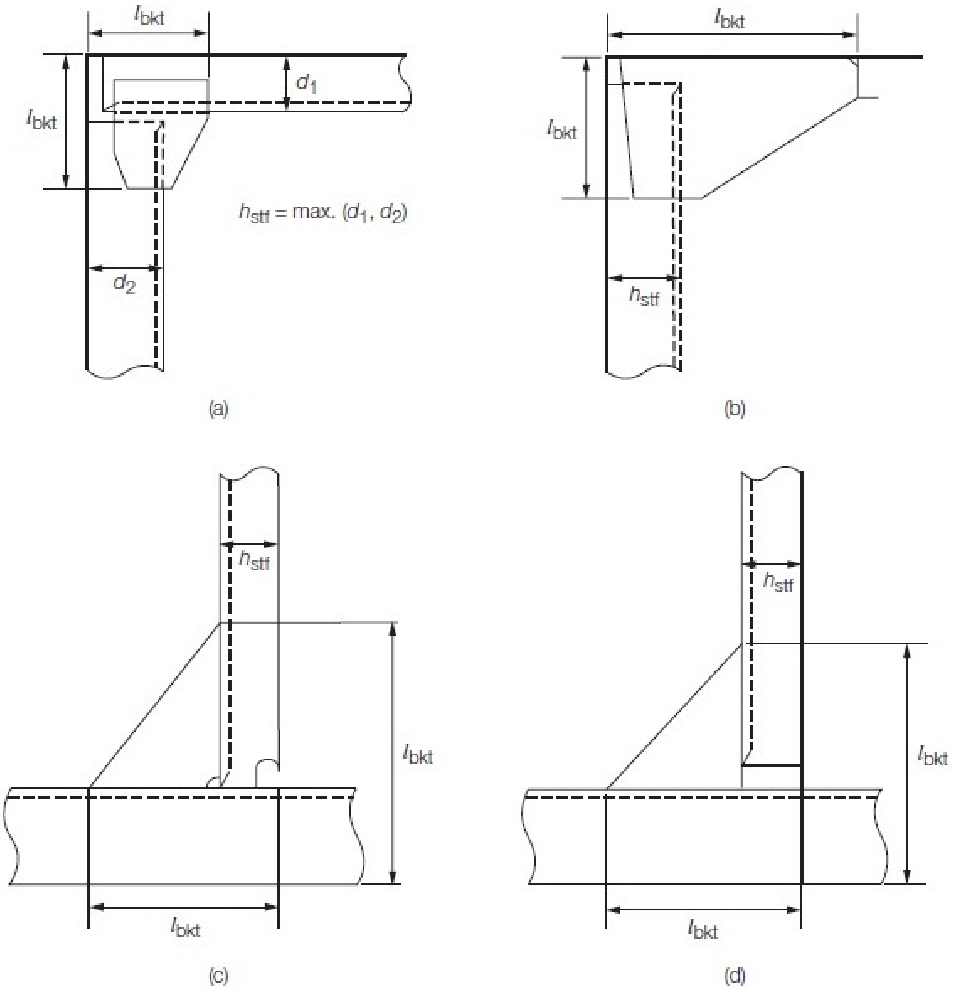
= 0,3 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3.

In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$\sigma_{yd\text{-}stf}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{yd\text{-}bkt}$ = specified minimum yield stress of the material of the bracket, in N/mm^2.



NOTE
For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf}, is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

Figure 3.1.8 Bracket arm length

(d) Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.4* The end brackets are to have arm lengths, l_{bkt} , not less than:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z_{r1-net}}{t_{bkt-net}}} \text{ mm, but is not to be less than:}$$

(i) 1,8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3* (c)

(ii) 2,0 times for other cases, see *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3* (a), (b) and (d)

where

c_{bkt} = 65 for brackets with flange or edge stiffener

= 70 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$t_{bkt\text{-}net}$ = minimum net bracket thickness, as defined in *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3*.

(e) Where an edge stiffener is required, the depth of stiffener web, d_w , is not to be less than:

$$d_w = 45\left(1 + \frac{Z_{r1-net}}{2000}\right) \text{ mm,}$$

but is not to be less than 50 mm

where

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener.

1.8.4 **Bracketless connections.**

(a) Local support members, for example, longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.2* and *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3*.
(b) Where alternative connections are adopted, the proposed arrangements will be specially considered.
(c) The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.8.5 **Sniped ends.**

(a) Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e. structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, $t_{p\text{-}net}$, is not less than:

$$t_{p\text{-}net} = c_1\sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{1000}} \text{ mm}$$

where

l = stiffener span, in metres

s = stiffener spacing, in mm

P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

(i) *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* in the cargo tank region
(ii) *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* in the area forward of the forward cargo tank, and in the aft end
(iii) *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1* in the machinery space

k = higher strength steel factor, as defined in *Pt 10, Ch 1, 3.1 General 3.1.7*

c_1 = coefficient for the design load set being considered, to be taken as:

= 1,2 for acceptance criteria set AC1

= 1,1 for acceptance criteria set AC2

= 1,0 for acceptance criteria set AC3.

(b) Bracket toes and sniped end members are, in general, to be kept within 25 mm of the adjacent member. The maximum distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

(c) The end attachments of non-load-bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50 mm of the adjacent member, unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm.

1.8.6 **Air and drain holes and scallops.**

(a) Air, drain holes, scallops and block fabrication butts are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the midspan and 50 mm measured along the length in the opposite direction, see *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.6*. In areas where the shear stress is less than 60 per cent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.6* shows some examples of air and drain holes and scallops. In general, the ratio of a/b, as defined in *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.6*, is to be between 0,5 and 1,0. In fatigue-sensitive areas, further consideration may be required with respect to the details and arrangements of openings and scallops.

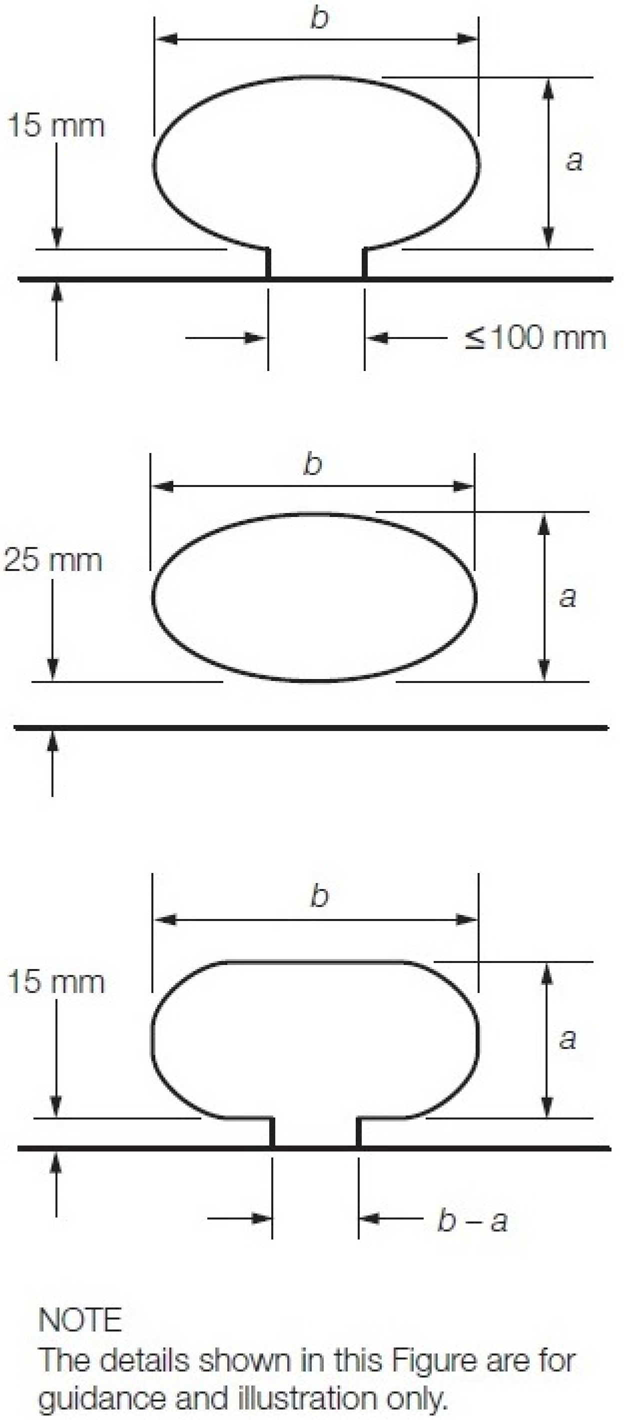


Figure 3.1.9 Examples of air and drain holes and scallops

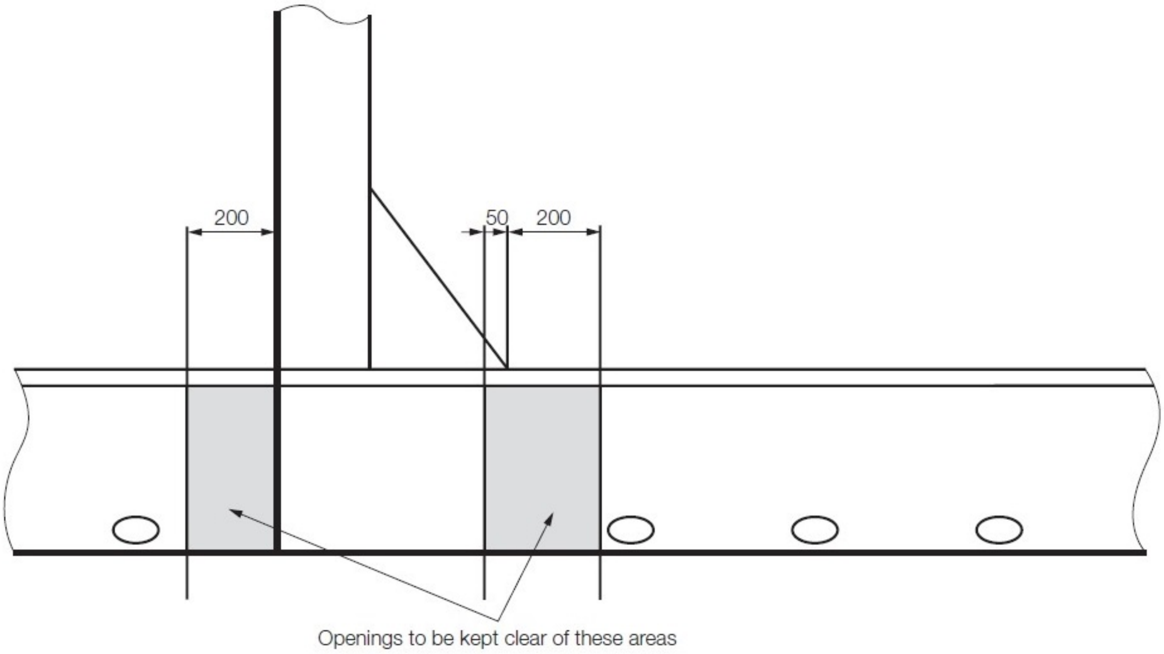


Figure 3.1.10 Location of air and drain holes

1.8.7 **Special requirements.**

(a) Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.6*, are not permitted in longitudinal strength members or within 20 per cent of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted, provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

1.9 Termination of primary support members

1.9.1 **General.**

(a) Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.
(b) The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

1.9.2 **End connection.**

(a) Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.
(b) The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in *Pt 10, Ch 3, 1.9 Termination of primary support members 1.9.3*.
(c) Where primary support members are subjected to concentrated loads, additional strengthening may be required, particularly if these are out of line with the member web.
(d) In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied, provided that there is adequate support of the adjoining face-plates.

1.9.3 **Brackets.**

(a) In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1,5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

(b) For a ring system where the end bracket is integral with the webs of the members and the face-plate is carried continuously along the edges of the members and the bracket, the full area of the largest face-plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face-plates. Butts in face-plates are to be kept well clear of the bracket toes.

(c) Where a wide face-plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face-plate abuts against a thinner one and the difference in thickness is greater than 4 mm, the taper of the thickness is not to be greater than 1 in 3.

(d) Face-plates of brackets are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$$A_{f\text{-}net} = l_{bkt\text{-}edge}\, t_{bkt\text{-}net} \text{ cm}$$

where

$l_{bkt\text{-}edge}$ = length of free edge of bracket, in metres. For brackets that are curved, the length of the free edge may be taken as the length of the tangent at the mid point of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1,5 m, 40 per cent of the face-plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0,15 m from the edge

$t_{bkt\text{-}net}$ = minimum net bracket thickness, in mm, as defined in *Pt 10, Ch 3, 1.8 Termination of local support members 1.8.3*.

1.9.4 **Bracket toes.**

(a) The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face-plate, it is to be sniped and tapered at an angle not greater than 30 degrees.

(b) Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face-plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face-plates are welded adjacent to the edge of primary support member brackets, an adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face-plate, is to be not less than 60 per cent of the full cross-sectional area of the face-plate, see *Pt 10, Ch 3, 1.9 Termination of primary support members 1.9.4*.

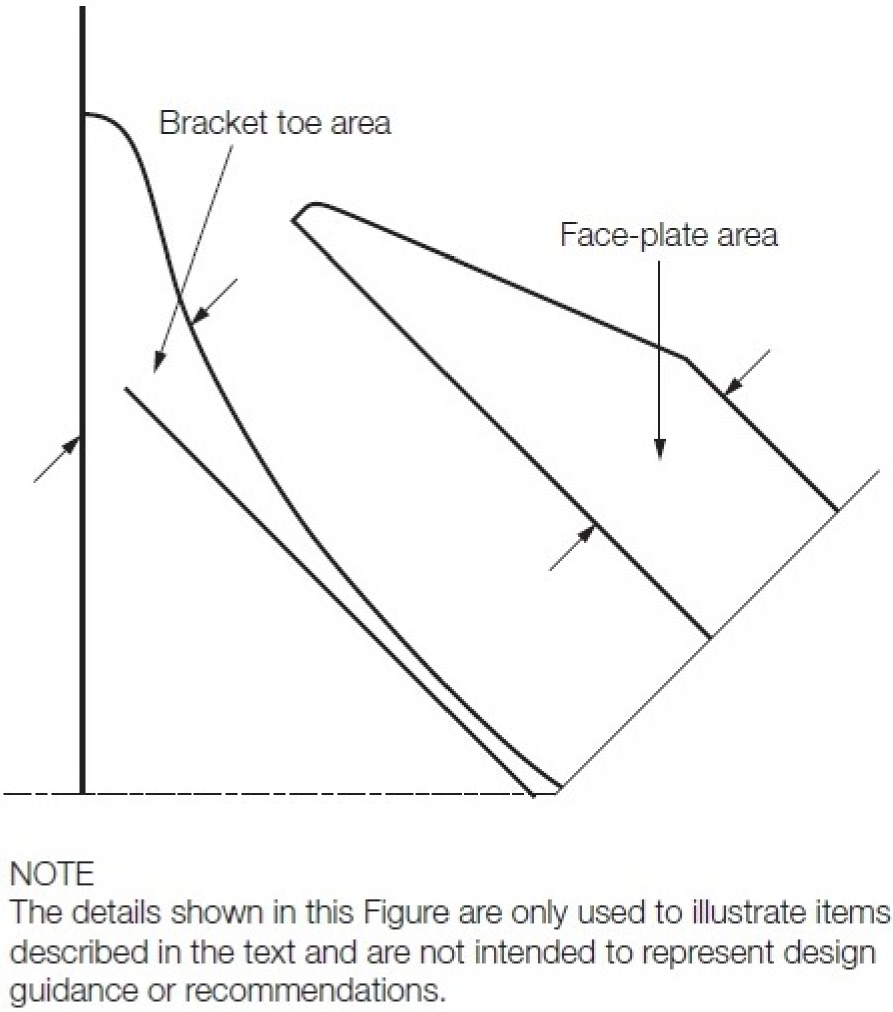


Figure 3.1.11 Bracket toe construction

1.10 Intersections of continuous local support members and primary support members

1.10.1 **General.**

(a) Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

(b) Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with 'full' collar plates, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.1*.

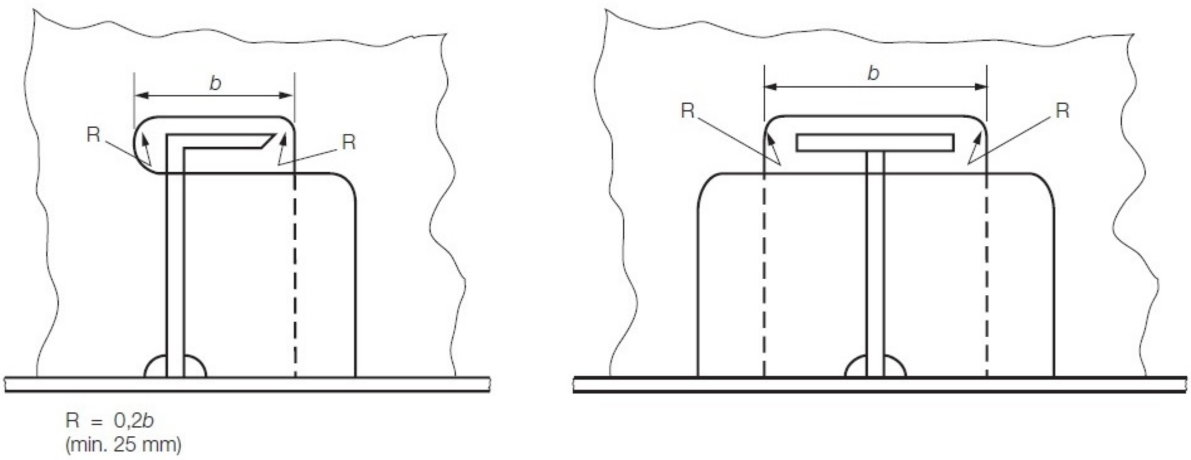


Figure 3.1.12 Collars for cut-outs in areas of high stress

(c) Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*, and in areas of significant stress concentrations, e.g. in way of primary support member toes.

(d) When, in the following locations, the calculated direct stress, σ_W, in the primary support member web stiffener according to *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* exceeds 80 per cent of the permissible values, a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(i) connection to shell envelope longitudinals below the deep load draught, T_{sc} ;

(ii) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads, where a back bracket is fitted or where the primary support member web is welded to the stiffener faceplate. The soft heel is to have a keyhole, similar to that shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* (c).

1.10.2 **Details of cut-outs.**

(a) In general, cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20 per cent of the breadth, *b*, of the cut-out or 25 mm, whichever is greater, but need not be greater than 50 mm, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.1*. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.10.3 **Connection between primary support members and intersecting stiffeners (local support members).**

(a) The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

(b) The total load, *W*, transmitted through the connection to the primary support member is given by:

$$W = Ps\left(S - \frac{s}{2000}\right)10^{-3}$$

where

P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2 in the cargo tank region

Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2 in the area forward of the forward cargo tank

Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2 in the aft end

Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1 in the machinery space
Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads if subjected to sloshing loads
Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads if subjected to bottom slamming loads
Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads if subjected to bow impact loads

S = primary support member spacing, in metres

s = stiffener spacing, in mm

For stiffeners having different primary support member spacing, S, and/or different pressure, P, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

(c) The load, W_1 , transmitted through the shear connection is to be taken as follows:

If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha + \frac{A_{1-net}}{4f_c A_{w-net} + A_{1-net}}\right) \text{ kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

where

W = the total load, in kN, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

α_a = panel aspect ratio, not to be taken greater than 0,25

$$= \frac{s}{1000S}$$

S = primary support member spacing, in metres

s = stiffener spacing, in mm

A_{1-net} = effective net shear area of the connection, to be taken as the sum of the components of the connection:

$A_{ld-net} + A_{lc-net}$ cm^2

in case of a slit type slot connections area, A_{1-net} , is given by:

$A_{l-net} = 2l_d\, t_{w-net}\, 10^{-2}$ cm^2

in case of a typical double lug or collar plate connection area, A_{l-net} , is given by:

$A_{l-net} = 2f_1\, l_c\, t_{c-net}\, 10^{-2}$ cm^2

A_{1d-net} = net shear connection area excluding lug or collar plate, as given by the following and *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*:

$A_{ld-net} = l_d\, t_{w-net}\, 10^{-2}$ cm^2

l_d = length of direct connection between stiffener and primary support member web, in mm

t_{w-net} = net web thickness of the primary support member, in mm

A_{1c-net} = net shear connection area with lug or collar plate, given by the following and *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*:

$A_{lc-net} = f_1\, l_c\, t_{c-net}$ 10–2 cm^2

l_c = length of connection between lug or collar plate and primary support member, in mm

$t_{c\text{-}net}$ = net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent primary support member web, in mm

f_1 = shear stiffness coefficient:

= 1,0 for stiffeners of symmetrical cross-section

= $\frac{140}{w}$ for stiffeners of asymmetrical cross-section but is not to be taken as greater than 1,0

w = the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

$A_{w\text{-}net}$ = effective net cross-sectional area of the primary support member web stiffener in way of the connection, including backing bracket where fitted, as shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*, in cm. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, $A_{w\text{-}net}$ is to be measured at the throat of the connection, as shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

f_c = the collar load factor defined as follows: for intersecting stiffeners of symmetrical cross-section:

= 1,85 for $A_{w\text{-}net} \leq 14$

= 1,85 – 0,0441 ($A_{w\text{-}net}$ – 14) for 14 < $A_{w\text{-}net} \leq 31$

= 1,1 – 0,013 ($A_{w\text{-}net}$ – 31) for 31 < $A_{w\text{-}net} \leq 58$

= 0,75 for $A_{w\text{-}net} > 58$

for intersecting stiffeners of asymmetrical cross-section:

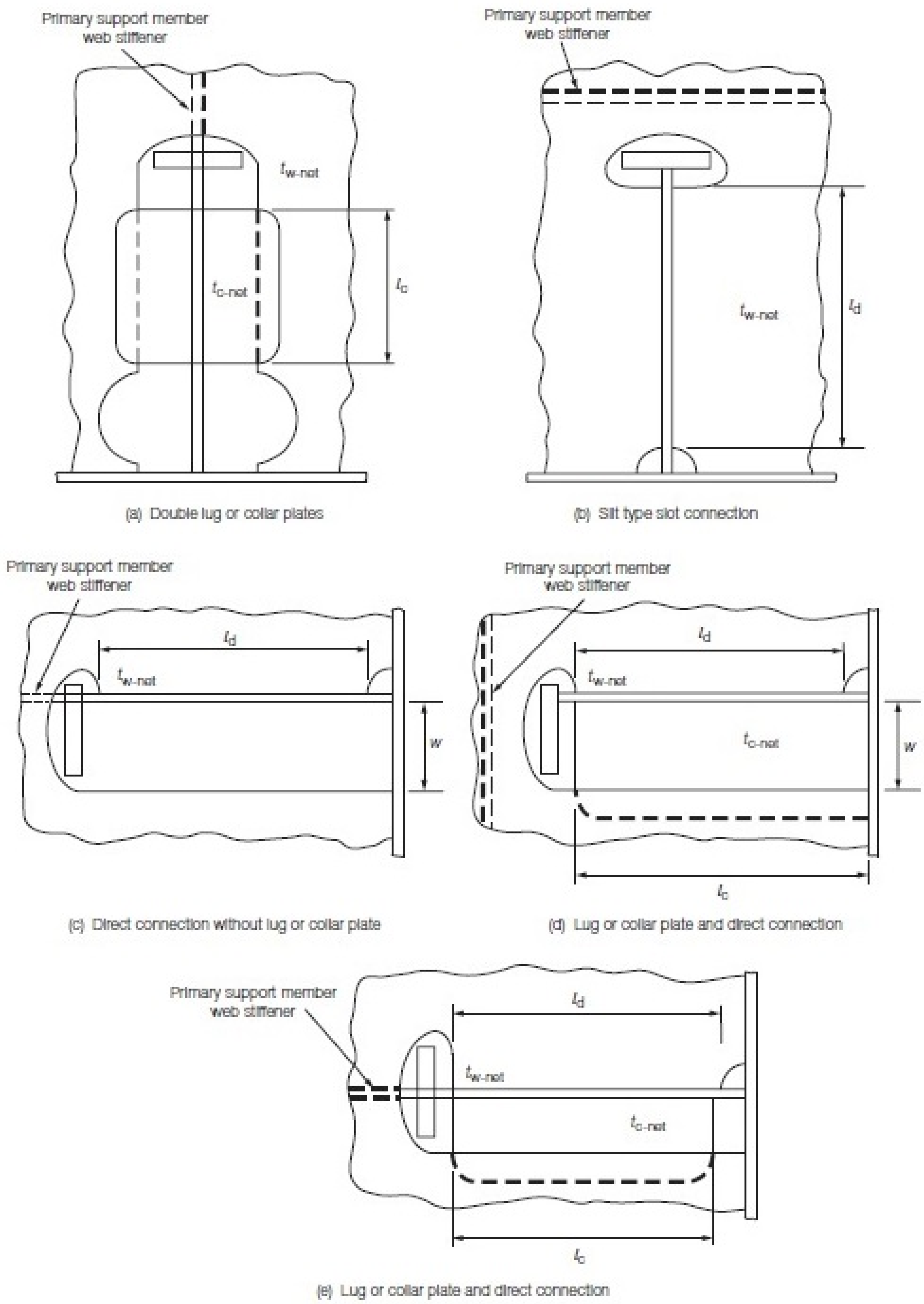
$$0,68 + 0,0172\frac{l_s}{A_{w-net}}$$

where

l_s = l_c for a single lug or collar plate connection to the primary support member

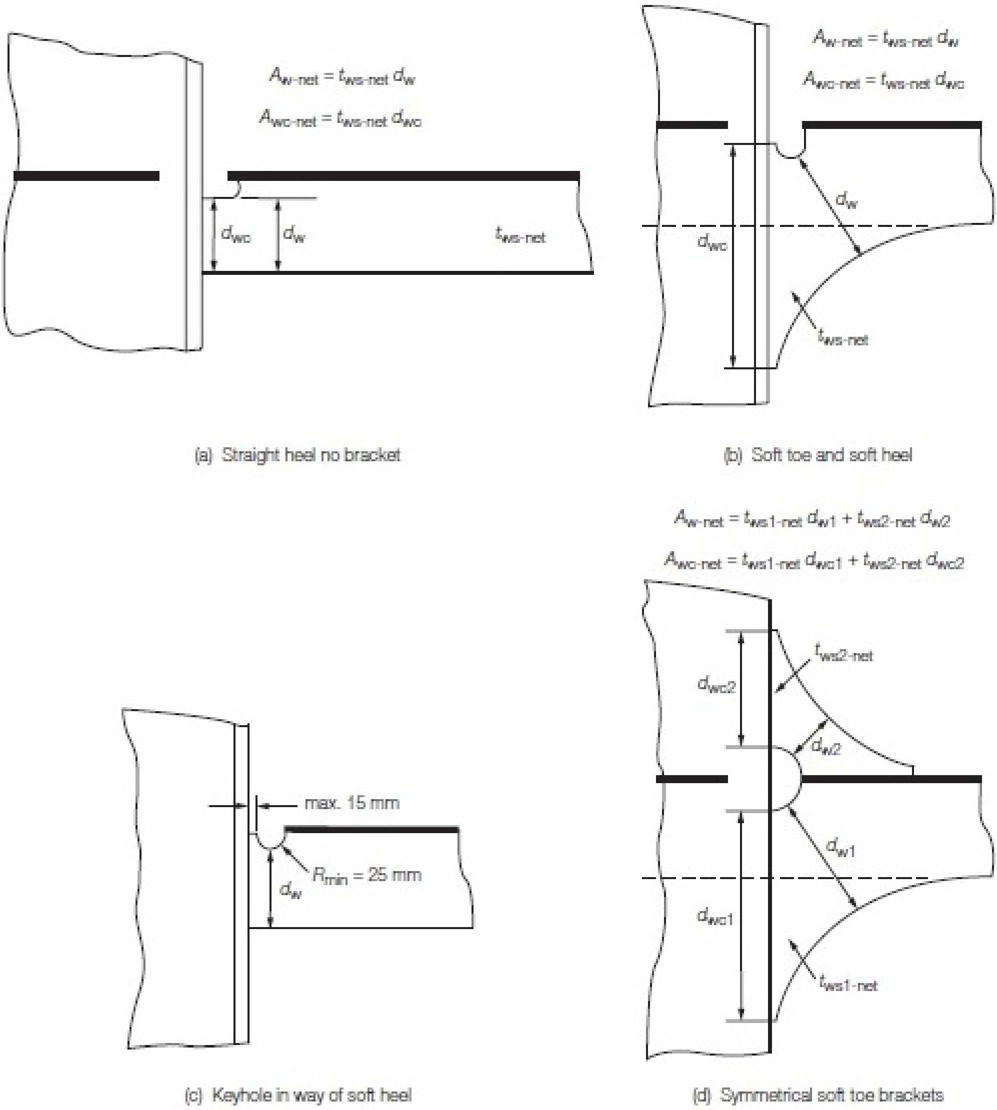
= l_d for a single sided direct connection to the primary support member

= mean of the connection length on both sides, i.e. in the case of a lug or collar plus a direct connection, $l_s = 0,5\,(l_c + l_d)$



NOTE
The details shown in this Figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Figure 3.1.13 Symmetric and asymmetric cut-outs



where

t_{ws-net}, $t_{ws1-net}$ and $t_{ws2-net}$	net thickness of the primary support member web stiffener/backing bracket, in mm
d_w, d_{w1} and d_{w2}	minimum depth of the primary support member web stiffener/backing bracket, in mm
d_{wc}, d_{wc1} and d_{wc2}	length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in mm

NOTE

Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see 1.10.1.4, the details shown in this Figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Figure 3.1.14 Primary support member web stiffener details

(d) The load, W_2 , transmitted through the primary support member web stiffener is to be taken as follows: If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

W_2 = 0

where

W = the total load, in kN, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

α_a = panel aspect ratio

S = primary support member spacing, in metres

s = stiffener spacing, in mm

$A_{1\text{-}net}$ = effective net shear area of the connection, in cm^2, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

f_c = collar load factor, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

$A_{w\text{-}net}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*.

(e) The values of $A_{w\text{-}net}$, $A_{wc\text{-}net}$ and $A_{1\text{-}net}$ are to be such that the calculated stresses satisfy the following criteria: for the connection to the primary support member web stiffener away from the weld:

$\sigma_w \le \sigma_{perm}$

for the connection to the primary support member web stiffener in way of the weld:

$\sigma_{wc} \le \sigma_{perm}$

for the shear connection to the primary support member web:

$\tau_w \le \tau_{perm}$

where

σ_w = direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:

$= \dfrac{10W_2}{A_{w-net}}$ N/mm^2

σ_{wc} = direct stress in the primary support member web stiffener in way of the weld connection:

$= \dfrac{10W_2}{A_{wc-net}}$ N/mm^2

τ_w = shear stress in the shear connection to the primary support member

$= \dfrac{10W_1}{A_{1-net}}$ N/mm^2

$A_{w\text{-}net}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

$A_{wc\text{-}net}$ = effective net area of the web stiffener in way of the weld as shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*, in cm^2

$A_{1\text{-}net}$ = effective net shear area of the connection, in cm^2, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

W_1 = load transmitted through the shear connection, in kN, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

W_2 = load transmitted through the web stiffener, in kN, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

σ_{perm} = permissible direct stress given in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* for the applicable acceptance criteria, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*, in N/mm^2

τ_{perm} = permissible shear stress given in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* for the applicable acceptance criteria, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*, in N/mm^2

when total load, *W*, is bottom slamming or bow impact loads, the following criteria apply in lieu of *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* to *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

$$0{,}9W \leq \frac{\left(A_{1-net}\,\tau_{perm} + A_{w-net}\,\sigma_{perm}\right)}{10} \text{ kN}$$

$A_{1\text{-}net}$ = effective net shear area in cm^2 of the connection, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

$A_{w\text{-}net}$ = effective net cross-sectional area in cm^2 of the primary support member web stiffener in way of the connection including backing bracket where fitted, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*

σ_{perm} = permissible direct stress given in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* for AC3, in N/mm^2

τ_{perm} = permissible shear stress given in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* for AC3, in N/mm^2.

Table 3.1.6 Permissible stresses for connection between stiffeners and primary support members

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set, *see Pt 10, Ch 3, 3.4 Side structure 3.4.3*			Acceptance criteria set, *see Pt 10, Ch 3, 3.4 Side structure 3.4.3*		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0{,}83\sigma_{yd}$, *see* Note 3	σ_{yd}	σ_{yd}	–	–	–
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0{,}58\sigma_{yd}$ *see* Note 3	$0{,}7\sigma_{yd}$ *see* Note 3	σ_{yd}	–	–	–
partial penetration weld	$0{,}83\sigma_{yd}$ *see* Notes 2 & 3	σ_{yd} *see* Note 2	σ_{yd}	–	–	–
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0{,}5\sigma_{yd}$	$0{,}6\sigma_{yd}$	σ_{yd}	–	–	–
Shear connection including lugs or collar plates:						
single sided connection	–	–	–	$0{,}71\tau_{yd}$	$0{,}85\tau_{yd}$	τ_{yd}

double sided connection	—	—	—	$0{,}83\sigma_{yd}$	τ_{yd}	τ_{yd}
Symbols						
τ_{perm} = permissible shear stress, in N/mm^2 σ_{perm} = permissible direct stress, in N/mm^2 σ_{yd} = minimum specified material yield stress, in N/mm^2 τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$, in N/mm^2						
NOTES 1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*. 2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener. 3. Allowable stresses may be increased by 5 per cent where a soft heel is provided in way of the heel of the primary support member web stiffener.						

(f) Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with, the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of A_{w-net} as shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*.

(g) Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g. lapped connections between transverse and longitudinal local support members.

(h) Fabricated stiffeners having their face-plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

(i) Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*. The offset primary support member web stiffener is to be located in close proximity to the slot edge, see also *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*. The ends of the offset web stiffeners are to be suitably tapered and softened.

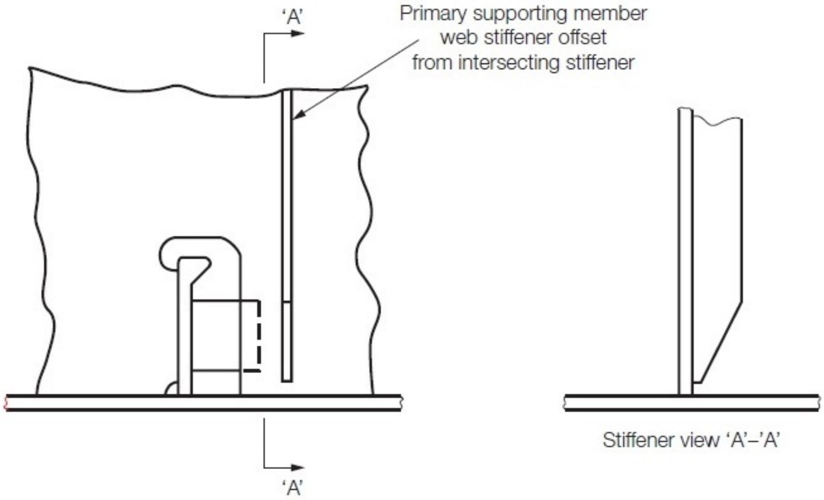


Figure 3.1.15 Offset primary support member web stiffeners

(j) Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

(k) The size of the fillet welds is to be calculated according to *Pt 4, Ch 8 Welding and Structural Details*, based on the weld factors given in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*. For the welding in way of the shear connection, the size is not to be less than that required for the primary support member web plate for the location under consideration.

Table 3.1.7 Weld factors for connection between stiffeners and primary support members

Item	Weld factor
Primary support member stiffener to intersecting stiffener	$0,6\sigma_w/\sigma_{perm}$ not to be less than 0,38
Shear connection inclusive lug or collar plate	0,38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0,6\sigma_w/\sigma_{perm}$ not to be less than 0,44
Symbol	
τ_w = shear stress, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* σ_w = direct stress, as defined in *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* τ_{perm} = permissible shear stress, in N/mm^2, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3* σ_{perm} = permissible direct stress, in N/mm^2, see *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members 1.10.3*	

1.11 Openings

1.11.1 **General.**

(a) Openings are to have well rounded corners.

(b) Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

  (i) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one sixth of their length from either end;
  (ii) in floors or double bottom girders close to their span ends;
  (iii) above the heads and below the heels of pillars.

  Where larger openings than given by *Pt 10, Ch 3, 1.11 Openings 1.11.2* or *Pt 10, Ch 3, 1.11 Openings 1.11.3* are proposed, the arrangements and compensation required will be specially considered.

1.11.2 **Manholes and lightening holes in single skin sections not requiring reinforcement.**

(a) Openings cut in the web with depth of opening not exceeding 25 per cent of the web depth and located so that the edges are not less than 40 per cent of the web depth from the face-plate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 per cent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut-outs for local support members.

1.11.3 **Manholes and lightening holes in double skin sections not requiring reinforcement.**

(a) Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required, provided that the depth of the opening does not exceed 50 per cent of the web depth and is located so that the edges are well clear of cut-outs for the passage of local support members.

1.11.4 **Manholes and lightening holes requiring reinforcement.**

(a) Manholes and lightening holes are to be stiffened as required by *Pt 10, Ch 3, 1.11 Openings 1.11.4* and *Pt 10, Ch 3, 1.11 Openings 1.11.4*.

(b) The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of *Pt 10, Ch 3 Scantling Requirements*, is greater than 50 N/mm^{2}2 for acceptance criteria set AC1 or greater than 60 N/mm^2 for acceptance criteria sets AC2 and AC3. The stiffening arrangement is to ensure buckling strength, as required by *Pt 10, Ch 3 Scantling Requirements*.

(c) On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shorter axis is less than 400 mm, and in both directions if the length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, see *Pt 10, Ch 3, 1.11 Openings 1.11.4*

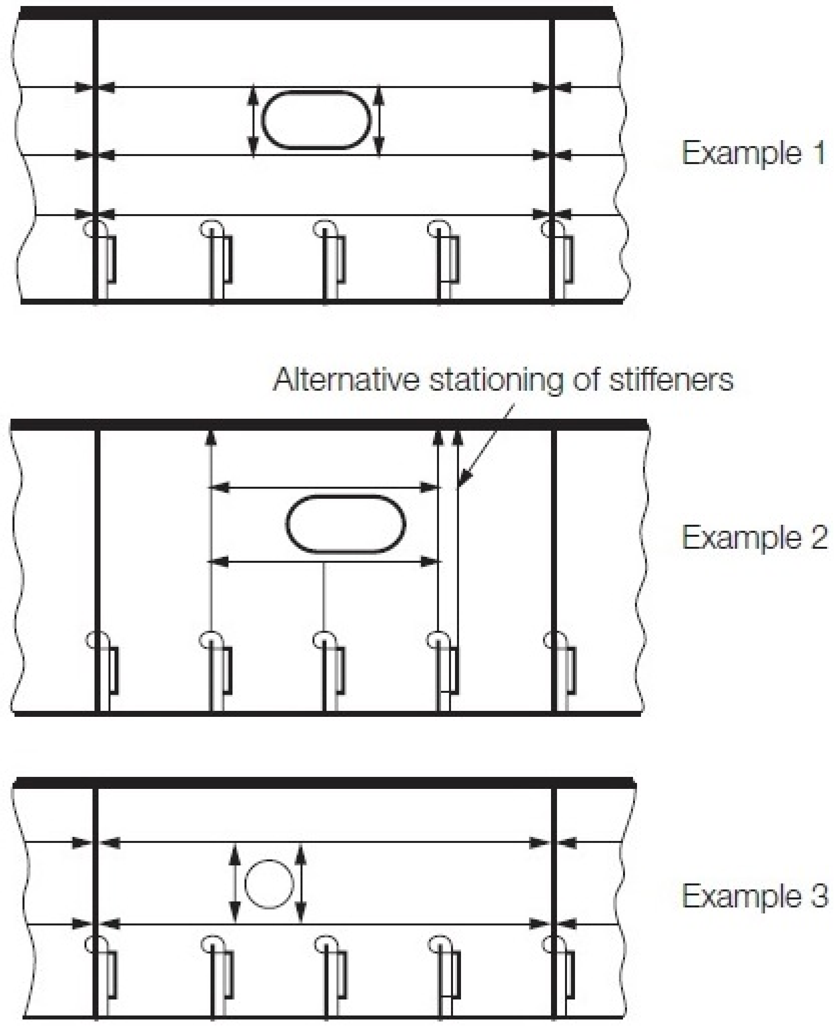


Figure 3.1.16 Web plate with large openings

1.12 Local reinforcement

1.12.1 **Reinforcement at knuckles.**

(a) Whenever a knuckle in a main member (shell, longitudinal bulkhead, etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear), see *Pt 10, Ch 3, 1.12 Local reinforcement 1.12.1*.

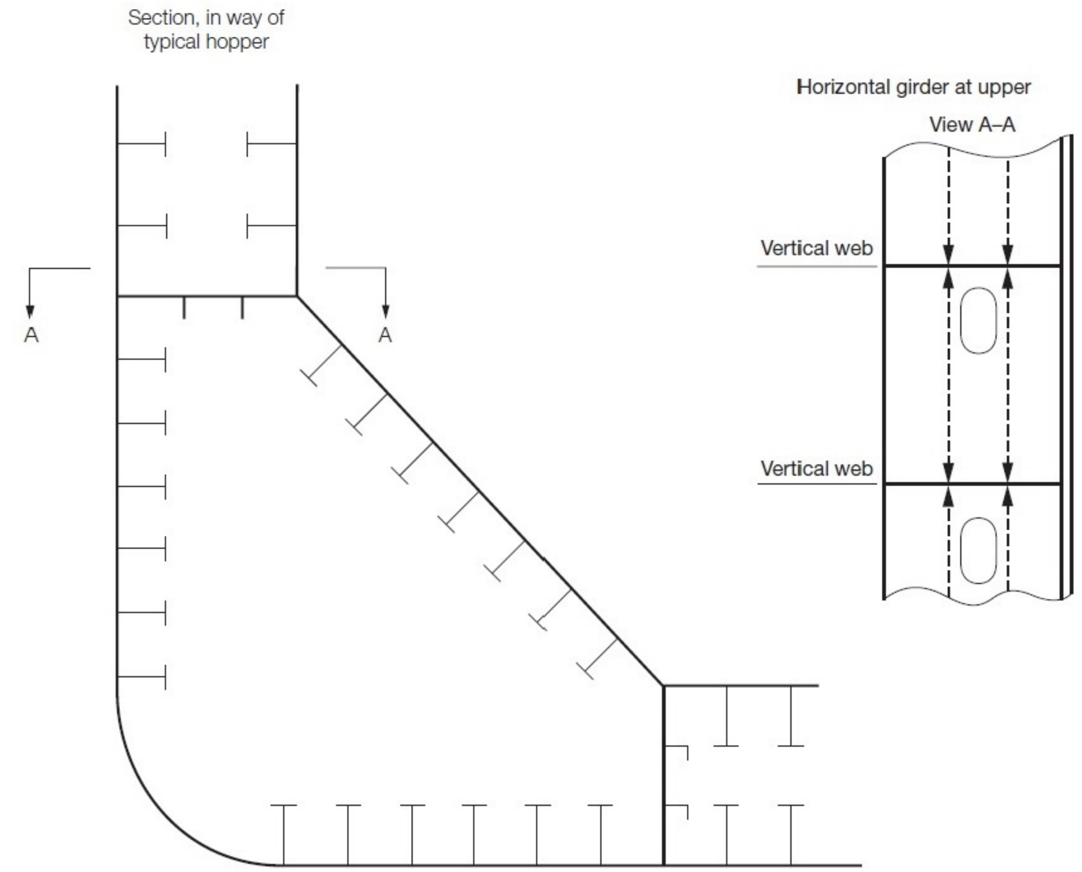


Figure 3.1.17 Example of reinforcement at knuckles

(b) In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high inplane loads across the knuckle, such as deck camber knuckles.

(c) Generally, the distance between the knuckle and the support stiffening described in *Pt 10, Ch 3, 1.12 Local reinforcement 1.12.1* is not to be greater than 50 mm.

1.12.2 **Reinforcement for openings and attachments associated with means of access for inspection/ maintenance purposes.**

(a) Local reinforcement is to be provided, taking into account proper location and strength of all attachments to the hull structure for access for inspection/maintenance purposes.

■ *Section 2* Cargo tank region

2.1 Symbols

2.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

B = moulded breadth, in metres

D = moulded depth, in metres

T_{SC} = deep load draught, in metres

T_{LT} = minimum design light load draught, in metres

E = modulus of elasticity, in N/mm^2

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

s = stiffener spacing, in mm

p = design pressure for the design load set being considered, in kN/m^2

g = acceleration due to gravity, 9,81 m/s^2

k = higher strength steel factor, defined in *Pt 10, Ch 1, 3.1 General 3.1.7*.

2.2 General

2.2.1 **Application.**

(a) The requirements of this Section apply to the hull structure within the cargo tank region of the ship unit.

2.2.2 **Evaluation of scantlings.**

(a) Structural design details are to comply with the requirements given in *Pt 10, Ch 3, 1.7 Standard construction details* to *Pt 10, Ch 3, 1.12 Local reinforcement*.

(b) The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

(c) Local scantlings are to be increased where applicable to account for:

- local variations, such as increased spacing or increased stiffener spans;
- green sea pressure loads;
- fore and aft end strengthening requirements, see *Pt 10, Ch 3, 3 Forward of the forward cargo tank* and *Pt 10, Ch 3, 5 Aft end*;
- local deflection requirements to limit interaction between the hull structure and liquefied gas cargo containment systems where fitted; and
- in way of anti-roll chocks, anti-flotation chocks and other similar items where fitted.

(d) Where the hull structure forms part of, or provides direct support to, a liquefied gas cargo containment system, the scantlings are to be sufficient to meet the requirements of the containment system design and the loads imposed by it. A structural analysis of the hull structure will be required using direct calculation procedures which are to be agreed with LR at as early a stage as possible.

(e) Where a membrane type liquefied gas cargo containment system is fitted inside the hull, the scantlings of the hull providing direct support to the containment system are to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. However, the tank pressure is to be taken as:

For static load cases:

$P_{\text{in-tk}} + P_{\text{o}}$

For dynamic load cases:

$P_{\text{in-tk}} + P_{\text{in-dyn}} + P_{\text{o}}$

where

P_o is the design vapour pressure defined in *Pt 11, Ch 4, 1.1 Definitions 1.1.2*.

For the operating and inspection/maintenance conditions the liquid density is to be taken as that of the liquefied gas cargo, see *Pt 10, Ch 2, 1.2 Definitions 1.2.3*.

The design of membrane tanks is to comply with *Pt 11, Ch 4 Cargo Containment*.

(f) Where an independent tank is fitted inside the hull, the scantlings of the hull structure surrounding, but not forming, part of the independent tank are to be as required for watertight boundaries. The scantlings of independent tanks are to comply with *Pt 11, Ch 4 Cargo Containment*.

2.2.3 **General scantling requirements.**

(a) The hull structure is to comply with the applicable requirements of:

- hull girder longitudinal strength, *see Pt 10, Ch 3, 1 Scantling requirements*;
- strength against sloshing and impact loads, *see Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads*;
- hull girder ultimate strength, *see* LR ShipRight Procedure for Ship Units;
- strength assessment (FEM), *see* LR ShipRight Procedure for Ship Units;
- fatigue strength, *see* LR ShipRight Procedure for Ship Units;
- buckling, see *Pt 10, Ch 1, 18 Buckling*.

(b) The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with *Pt 10, Ch 1, 12 Corrosion additions*.

2.2.4 **Minimum thickness for plating and local support members.**

(a) The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in *Pt 10, Ch 3, 2.2 General 2.2.4*.

Table 3.2.1 Minimum net thickness for plating and local support members in the cargo tank region

Scantling location			Net thickness (mm)
Plating	Shell	Keel plating	$6,0 + 0,04L_2$
		Bottom shell/bilge/side shell	$4,5 + 0,03L_2$
	Upper deck		$4,5 + 0,02L_2$
	Other structure	Hull internal tank boundaries	$4,5 + 0,02L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4,5 + 0,01L_2$
Local support members	Local support members on tight boundaries		$3,5 + 0,015L_2$
	Local support members on other structure		$2,5 + 0,015L_2$
Tripping brackets			$5,0 + 0,015L_2$

2.2.5 **Minimum thickness for primary support members.**

(a) The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in *Pt 10, Ch 3, 2.2 General 2.2.5*.

Table 3.2.2 Minimum net thickness for primary support members in cargo tank region

Scantling location	Net thickness (mm)
Bottom centreline girder	$5,5 + 0,025L_2$
Other bottom girders	$5,5 + 0,02L_2$

Bottom floors, web plates of side transverses and stringers in double hull	$5{,}0 + 0{,}015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverses (above and below upper deck) and cross ties	$5{,}5 + 0{,}015L_2$

2.3 Hull envelope plating

2.3.1 **Keel plating.**

(a) Keel plating is to extend over the flat of bottom for the complete length of the ship unit. The breadth, b_{kl} , is not to be less than:

$$b_{kl} = 800 + 5L_2 \text{ mm.}$$

(b) The thickness of the keel plating is to comply with the requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

2.3.2 **Bottom shell plating.**

(a) The thickness of the bottom shell plating is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

Table 3.2.3 Thickness requirements for plating

The minimum net thickness, t_{net} , is to be taken as the greatest value for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and given by

$$t_{net} = 0,0158\, \alpha_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \text{ mm}$$

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0
AC3	All members		1,0	0	1,0

where

α_p = correction factor for the panel aspect ratio

= $1,2 - \dfrac{s}{2100 l_p}$ but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing of primary support members, *S*, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered

= $\beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

= $\left(\dfrac{(z - z_{NA-net50}) M_{v-total}}{I_{v-net50}} - \dfrac{y M_{h-total}}{I_{h-net50}}\right) 10^{-3}$ N/mm^2

$M_{v\text{-}total}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-}perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}

$M_{h\text{-}total}$ = design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

$I_{h\text{-}net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4

y = transverse coordinate of load calculation point, in metres

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

2.3.3 **Bilge plating.**

(a) The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, *see Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*, or adjacent side shell plating, *see Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*, whichever is the greater.

(b) The net thickness of bilge plating, t_{net} , without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2 S_t P_{ex}}}{100} \text{ mm}$$

where

P_{ex} = design sea pressure from *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* calculated at the lower turn of bilge, in kN/m^2

r = effective bilge radius

= r_0 + 0,5 (a + b) mm

r_0 = radius of curvature, in mm, see *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.3*

S_t = distance between transverse stiffeners, webs or bilge brackets, in metres

a = distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.3* and *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.1*. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero

b = distance between the upper turn of bilge and the lowest side longitudinal, in mm, see *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.3* and *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.1*. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero

Where the plate seam is located in the flat plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge, provided that the plate seam is not more than S_b /4 below the lowest side longitudinal. Similarly, for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied, provided that the plate seam is not more than S_a /4 beyond the outboard bottom longitudinal. Regularly longitudinally-stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as 'longitudinal stiffening' for the application of this requirement.

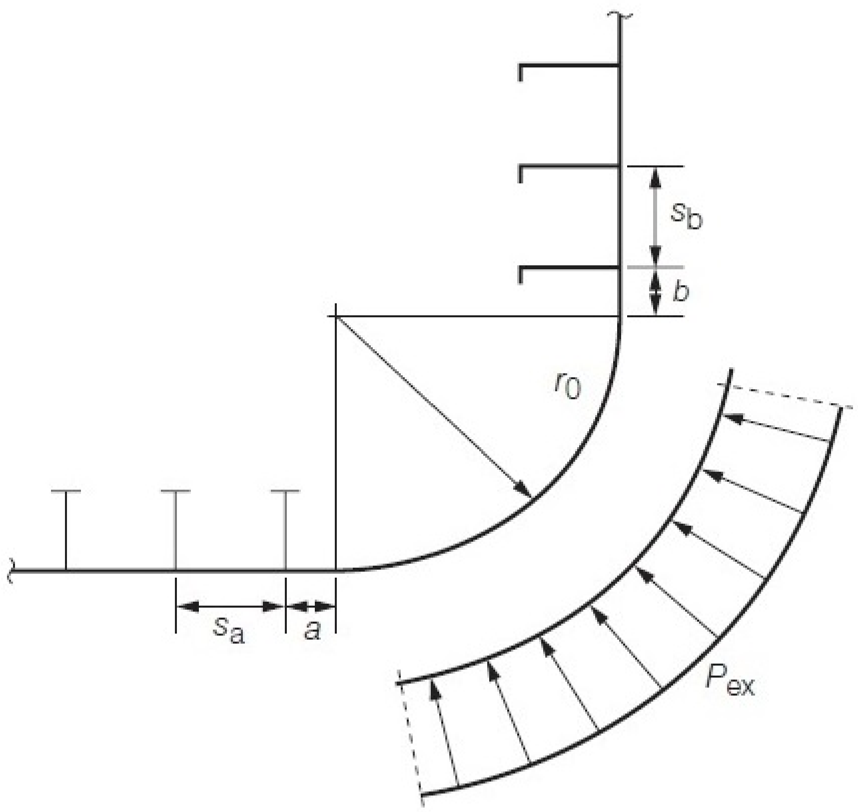


Figure 3.2.1 Unstiffened bilge plating

(c) Where bilge longitudinals are omitted, the bilge plate thickness outside 0,4L amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside 0,4L amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.3.4 **Side shell plating.**

(a) The thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

(b) The net thickness, t_{net} , of the side plating within the range as specified in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4* is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000}0,7\right)\left(\frac{BT_{SC}}{\sigma_{yd^2}}\right)^{0,25} \text{ mm}$$

(c) The thickness in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4* is to be applied to the following extent of the side shell plating, see *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*:

(i) longitudinal extent:

- between a section aft of amidships where the breadth at the waterline exceeds 0,9*B*, and a section forward of amidships where the breadth at the waterline exceeds 0,6*B*.

(ii) vertical extent:

- between 300 mm below the minimum design waterline at the light load draught, T_{LT} , amidships to 0,25T_{SC} or 2,2 m, whichever is greater, above the draught T_{SC} .

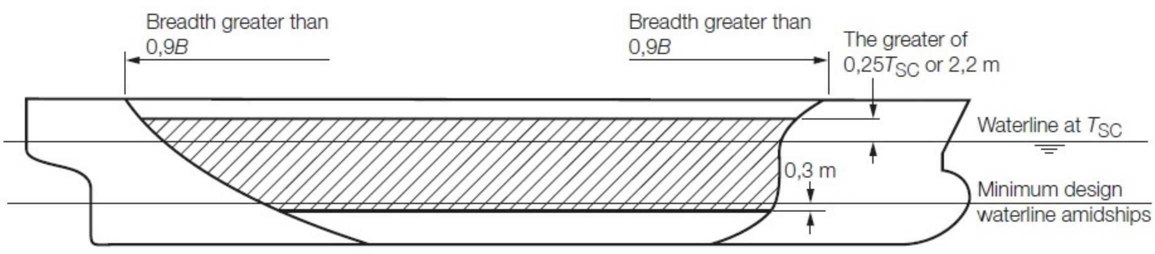


Figure 3.2.2 Extent of side shell plating

2.3.5 **Sheerstrake.**

(a) The sheerstrake is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*.

(b) The welding of deck fittings to rounded sheerstrakes is to be avoided within 0,6*L* of amidships.

(c) Where the sheerstrake extends above the deck stringer plate, the top edge of the sheerstrake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges. Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.3.6 **Deck plating.**

(a) The thickness of the deck plating is to comply with the requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

2.4 Hull envelope framing

2.4.1 **General.**

(a) The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Suitable alternatives which take account of resistance to buckling will be specially considered.

(b) Where longitudinals are omitted in way of the bilge, a longitudinal is to be fitted at the bottom and at the side, close to the position where the curvature of the bilge plate starts. The distance between the lower turn of bilge and the outermost bottom longitudinal, *a*, is generally not to be greater than one third of the spacing between the two outermost bottom longitudinals, s_a . Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, *b*, is generally not to be greater than one third of the spacing between the two lowest side longitudinals, s_b . See *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.3*.

2.4.2 **Scantling criteria.**

(a) The section modulus and thickness of the hull envelope framing are to comply with the requirements given in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* and *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*.

Table 3.2.4 Section modulus requirements for stiffeners

The minimum net section modulus, Z_{net} , is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and given by:

$$Z_{net} = \frac{|P| s l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

f_{bdg} = bending moment factor:

= 12 for horizontal stiffeners

= for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:

= 10 for vertical stiffeners

for stiffeners with reduced end fixity, see *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

l_{bdg} = effective bending span, in metres

C_s = permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0,85	1,0	0,75
	Transverse or vertical member	0,75	0	0,75
AC2	Longitudinal strength member	1,0	1,0	0,9
	Transverse or vertical member	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9
AC3	All members	1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$$= \left(\frac{(z - z_{NA-net50})M_{v-total}}{I_{v-net50}} - \frac{yM_{h-net50}}{I_{h-net50}}\right) \text{ N/mm}^2$$

$M_{v-total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm. $M_{v-total}$ is to be calculated in accordance with *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations* using the permissible hogging or sagging still water bending moment, $M_{sw-perm}$, to be taken as:

Stiffener location	$M_{sw-perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

$M_{h-total}$ = design horizontal bending moment at longitudinal position under consideration for the design load set being considered, in kNm

$I_{v-net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

$I_{h-net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4

y = transverse coordinate of the reference point, in metres

z = vertical coordinate of the reference point, in metres

$z_{NA-net50}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.2.5 Web thickness requirements for stiffeners

The minimum net web thickness, t_{w-net} , is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and given by

$$t_{w-net} = \frac{f_{shr}|P|sl_{shr}}{d_{shr}C_t\tau_{yd}} \text{ mm}$$

where

f_{shr} = shear force distribution factor:

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:

= 0,5 for horizontal stiffeners

= 0,7 for vertical stiffeners

for stiffeners with reduced end fixity, see *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

d_{shr} = effective shear depth, in mm

C_t = permissible shear stress coefficient for the design load set being considered, to be taken as

= 0,75 for acceptance criteria set AC1

= 0,90 for acceptance criteria set AC2

= 1,0 for acceptance criteria set AC3

2.5 Inner bottom

2.5.1 **Inner bottom plating.**

(a) The thickness of the inner bottom plating is to comply with the requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

(b) In way of a welded hopper knuckle, the inner bottom is to be scarphed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

(c) In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom.

2.5.2 **Inner bottom longitudinals.**

(a) The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* and *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*.

2.6 Bulkheads

2.6.1 **General.**

(a) The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*.

(b) Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.6.2 **Longitudinal tank boundary bulkhead plating.**

(a) The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

(b) Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarphed into the adjoining structure.

2.6.3 **Hopper side structure.**

(a) Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.6.4 **Transverse tank boundary bulkhead plating.**

(a) The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*.

2.6.5 **Tank boundary bulkhead stiffeners.**

(a) The section modulus and web thickness of stiffeners on longitudinal or transverse tank boundary bulkheads are to comply with the requirements given in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* and *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*.

2.6.6 **Corrugated bulkheads.**

(a) In general, corrugated bulkheads are to be designed with the corrugation angles, φ, between 55° and 90°, *see Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*.

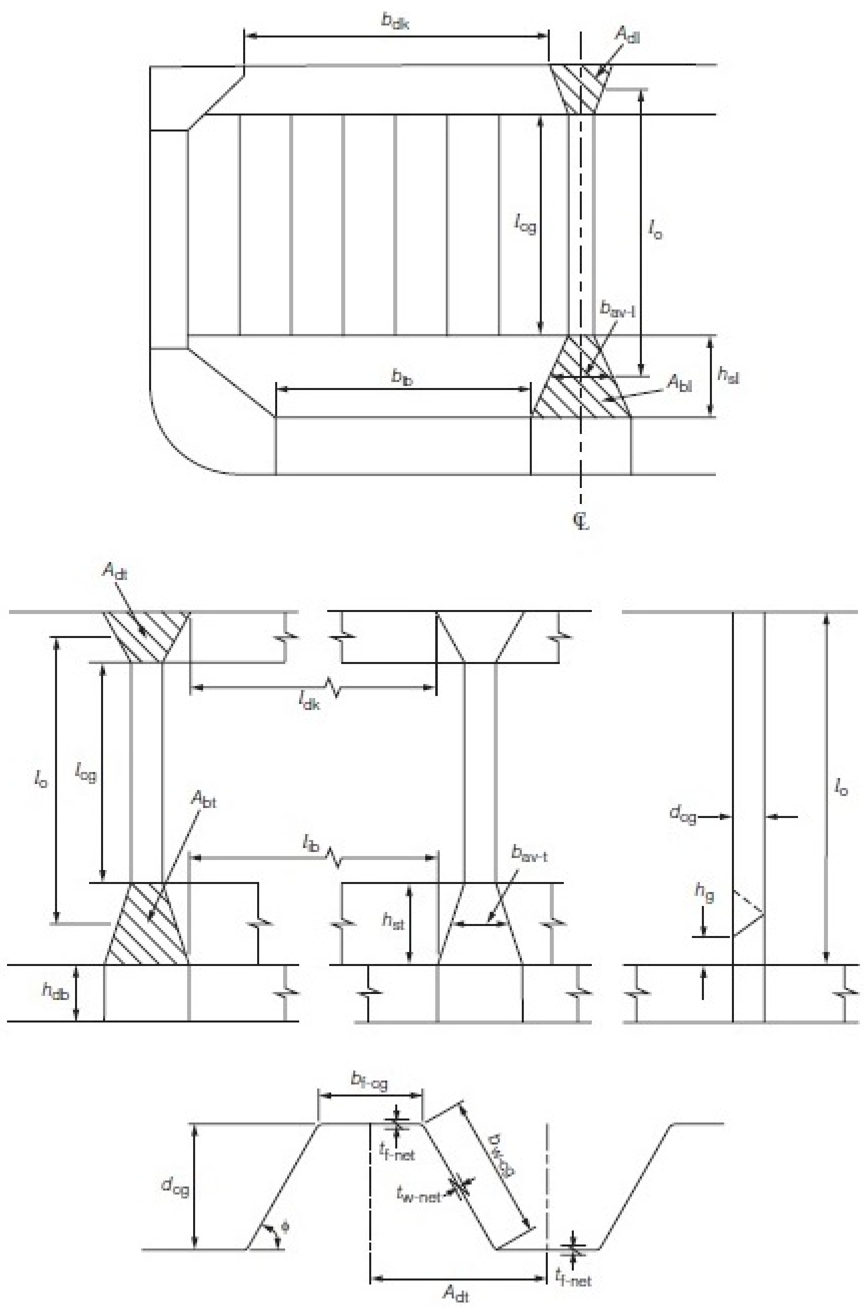


Figure 3.2.3 Definition of parameters for corrugated bulkhead (units with longitudinal bulkhead at centreline)

(b) The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model, in accordance with the LR ShipRight Procedure for Ship Units, in the midship region. The global strength of corrugated bulkheads outside of midship region is to be considered, based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

(c) The net thicknesses, t_{net} , of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and given by

t_{net} = $0,0158 b_p \sqrt{\dfrac{|P|}{C_a \sigma_{yd}}}$ mm

where

b_p = breadth of plate:

= b_f for flange plating, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

= b_w for web plating, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

C_a = permissible bending stress coefficient

= 0,75 for acceptance criteria set AC1

= 0,90 for acceptance criteria set AC2

= 1,0 for acceptance criteria set AC3.

(d) Where the corrugated bulkhead is built with flange and web plate of different thickness, the thicker net plating thickness, t_{m-net} , is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and given by:

t_{m-net} = $\sqrt{\dfrac{0,0005 b_p^2 |P|}{C_a \sigma_{yd}} - t_{n-net}^2}$ mm

where

t_{n-net} = net thickness of the thinner plating, either flange or web, in mm

b_p = breadth of thicker plate, either flange or web, in mm

C_a = permissible bending stress coefficient

= 0,75 for acceptance criteria set AC1

= 0,90 for acceptance criteria set AC2

= 1,0 for acceptance criteria set AC3.

2.6.7 **Vertically corrugated bulkheads.**

(a) In addition to the requirements of *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*, vertically corrugated bulkheads are also to comply with the following requirements.

(b) The net plate thicknesses as required by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* are to be maintained for two thirds of the corrugation length, l_{cg} , from the lower end, where l_{cg} is as defined in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*. Above that, the net plate thickness may be reduced by 20 per cent.

(c) Where a lower stool is fitted, the net web plating thickness of the lower 15 per cent of the corrugation, t_{w-net} , is to be taken as the greatest value calculated for all applicable design load sets from *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

t_{w-net} = $\dfrac{1000 \left| Q_{cg} \right|}{d_{cg} C_{t-cg} \tau_{yd}}$ mm

where

Q_{cg} = design shear force imposed on the web plating at the lower end of the corrugation

= $\dfrac{s_{cg} l_{cg} \left| 3P_1 + P_u \right|}{8000}$ kN

P_1 = design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2

P_u = design pressure for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2

s_{cg} = spacing of corrugation, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

l_{cg} = length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in metres, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

d_{cg} = depth of corrugation, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

$C_{t\text{-}cg}$ = permissible shear stress coefficient

= 0,75 for acceptance criteria set AC1

= 0,90 for acceptance criteria set AC2

= for acceptance criteria set AC3.

Table 3.2.6 Design load sets for plating and local support members (see continuation)

Structural member			Space type	Operation on site			Inspection/maintenance			Transit			Flooded		
				Draught	S Load	S+D Load	Draught	S Load	S+D Load	Draught	S Load	S+D Load	Draught	S Load	S+D Load
EXTERNAL MEMBERS	Acceptance criteria				AC1	AC2		AC1	AC2		AC1	AC2		AC2	AC3
	Exposed deck	Space above deck	Green sea	Deep load		P_{ex}	Deep load		P_{ex}	Deep load		P_{ex}	Flooded		P_{ex}
		Space below deck	Tanks designed for liquid filing	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												

	Bilge, side shell, sheerstrake	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												
	Keel, bottom shell	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Space above the panel	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}			

INTERNAL MEMBERS	Inner decks, inner bottom tanktops	Space above deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Flooded	P_{dk} $+P_{in}$	P_{dk} $+P_{in}$
		Space below deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

	Bilge, side shell, sheerstrake	Outboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

INTERNAL MEMBERS	Transverse bulkheads	Space forward of bulkhead	Tanks designed for liquid	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
		Space aft of bulkhead	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

NOTES

1. When the unit's configuration cannot be described by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents, and are to maximise the pressure on the structural boundary. The applicable draught is to be taken in accordance with the Design Load Set and this Table. Design Load Sets covering the S and S+D design load combinations are to be selected.

2. Load cases for exposed decks are to consider any other distributed or concentrated loads, whereby simultaneously occurring green sea pressure may be ignored. Load cases for internal decks are to consider any other distributed or concentrated loads when green sea pressure is not applicable.

3. Ship motion parameters of GM and k_r are to be selected according to the loading condition.

4. Light load draught to be taken as the minimum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The minimum draught may vary between load scenarios.

5. Deep load draught to be taken as the maximum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The maximum draught may vary between load scenarios.

6. Draughts for flooded conditions to be taken as the deepest flooded draught in way of compartment under assessment.

7. Under the assumption that the ship unit is at sea, external sea pressure will always be present. Therefore, the design load set to assess the external shell envelope when the dominant load direction is from inside the hull outwards may be taken as P_{in} -P_{ex} .

(d) The depth of the corrugation, d_{cg} , is not to be less than:

$$d_{cg} = \frac{1000 l_{cg}}{15} \text{ mm}$$

where

l_{cg} = length of corrugation, defined as the distance between the lower stool (or inner bottom if no lower stool is fitted) and the upper stool (or upper end if no upper stool is fitted), in metres, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*.

(e) Where a lower stool is fitted, the net thickness of the lower two thirds of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

$$t_{f\text{-}net} = \frac{0,00657 b_f \sqrt{\sigma_{bdg-max}}}{C_f} \text{ mm}$$

where

$\sigma_{bdg\text{-}max}$ = maximum vertical bending stress in the flange. The bending stress is to be calculated at the lower end and at the midspan of the corrugation length

$$= \frac{1000 M_{cg}}{Z_{cg-act-net}} \text{ N/mm}^2$$

M_{cg} = as defined in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*

$Z_{cg\text{-}act\text{-}net}$ = actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3

b_f = breadth of flange plating, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

b_w = breadth of web plating, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

C_f = coefficient

$$= 7,65 - 0,25\left(\frac{b_w}{b_f}\right)^2$$

(f) Where a lower stool is fitted, the net section modulus at the lower and upper ends and at the mid length of the corrugation, $Z_{cg\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

$$Z_{cg\text{-}net} = \frac{1000 M_{cg}}{C_{s-cg}\,\sigma_{yd}} \text{ cm}^3$$

where

$$M_{cg} = \frac{C_i |P| s_{cg} l_o^2}{12000} \text{ kNm}$$

$$P = \frac{P_u + P_1}{2} \text{ kN/m}^3$$

P_l, P_u = design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2: for transverse corrugated bulkheads, the pressures are to be calculated at a section located at b_{tk} /2 from the longitudinal bulkheads of each tank

for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} = maximum breadth of tank under consideration measured at the bulkhead, in metres

s_{cg} = spacing of corrugation, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

l_o = effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in metres, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

l_{cg} = length of corrugation, defined as the distance between the lower stool and the upper stool, or the upper end where no upper stool is fitted, in metres, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

C_i = the relevant bending moment coefficients, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*

$C_{s\text{-}cg}$ = permissible bending stress coefficient at middle of the corrugation length, l_{cg}

= c_e , but not to be taken as greater than 0,75 for acceptance criteria set AC1

= c_e , but not to be taken as greater than 0,90 for acceptance criteria set AC2

= c_e , but not to be taken as greater than 1,0 for acceptance criteria set AC3

at the lower and upper ends of corrugation length, l_{cg}

= 0,75 for acceptance criteria set AC1

= 0,90 for acceptance criteria set AC2

= 1,0 for acceptance criteria set AC3

c_e = $\dfrac{2,25}{\beta} - \dfrac{1,25}{\beta^2}$ for $\beta \geq 1,25$

= 1,0 for $\beta < 1,25$

β = $\dfrac{b_f}{t_{f-net}}\sqrt{\dfrac{\sigma_{yd}}{E}}$

b_f = breadth of flange plating, in mm, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

$t_{f\text{-}net}$ = net thickness of the corrugation flange, in mm.

Table 3.2.7 Values of Ci

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	$0,80C_{m1}$
Longitudinal bulkhead	C_3	C_{m3}	$0,65C_{m3}$

where

c_1 = $a_1 + b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,60

a_1 = $0,95\dfrac{0,41}{R_{bt}}$

b_1 = $-0,20 + \dfrac{0,078}{R_{bt}}$

C_{m1} = $a_{m1} + b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,55

a_{m1} = $0,63 + \dfrac{0,25}{R_{bt}}$

b_{m1} = $-0,25 - \frac{0,11}{R_{bt}}$

C_3 = $a_3 + b_3\sqrt{\frac{A_{d1}}{l_{dk}}}$ but is not to be taken as less than 0,60

a_3 = $0,86 - \frac{0,35}{R_{b1}}$

b_3 = $-0,17 + \frac{0,10}{R_{b1}}$

C_{m3} = $a_{m3} + b_{m3}\sqrt{\frac{A_{d1}}{l_{dk}}}$ but is not to be taken as less than 0,55

a_{m3} = $0,32 + \frac{0,24}{R_{b1}}$

b_{m3} = $-0,12 - \frac{0,10}{R_{b1}}$

R_{bt} = $\frac{A_{bt}}{b_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-t}}{h_{st}}\right)$ for transverse bulkheads

R_{bl} = $\frac{A_{b1}}{l_{ib}}\left(1 + \frac{l_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-1}}{h_{s1}}\right)$ for longitudinal bulkheads

A_{dt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2

= 0 if no upper stool is fitted

=

A_{dl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2

= 0 if no upper stool is fitted

A_{bt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2

A_{bl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2

b_{av-t} = average width of transverse bulkhead lower stool, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

b_{av-1} = average width of longitudinal bulkhead lower stool, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

h_{st} = height of transverse bulkhead lower stool, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

h_{sl} = height of longitudinal bulkhead lower stool, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

b_{ib} = breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

b_{dk} = breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

l_{ib} = length of cargo tank at the inner bottom level between transverse lower stools, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

l_{dk} = length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in metres. See *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*

(g) For tanks with effective sloshing breadth, b_{slh} , greater than 0,56B or effective sloshing length l_{slh} , greater than 0,13L, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation.

(h) For ship units with a moulded depth equal to or greater than 16 m, a lower stool is to be fitted in compliance with the following requirements:

(i) general:

- the height and depth are not to be less than the depth of the corrugation;
- the lower stool is to be fitted in line with the double bottom floors or girders;
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(ii) stool top plating:

- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(iii) stool side plating and internal structure:

- within the region of the corrugation depth from the stool top plate, the net thickness of the stool side plate is not to be less than 90 per cent of that required by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength;
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.2*, *Pt 10, Ch 3, 2.6 Bulkheads 2.6.4* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.5*for transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80 per cent of the required thickness of the corrugation webs and is to be of at least the same material yield strength;
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

(i) For ship units with a moulded depth less than 16 m, the lower stool may be eliminated, provided the following requirements are complied with:

(i) general:

- Double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively;
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable, gusset plates with shedder plates are to be fitted, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* below and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*;
- the corrugated bulkhead and its supporting structure are to be assessed by Finite Element (FE) analysis, in accordance with the LR ShipRight Procedure for Ship Units. In addition, the local scantlings requirements of *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6* and the minimum corrugation depth requirement of *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* are to be applied.

(ii) Inner bottom and hopper tank plating:

- The inner bottom and hopper tank in way of the corrugation are to be of at least the same material yield strength as the attached corrugation.

    (iii) Supporting structure:

- Within the region of the corrugation depth below the inner bottom, the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end, and is to be of at least the same material yield strength;
- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure;
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0,5 times the corrugation depth and a net thickness not less than 80 per cent of the net thickness of the corrugation webs and are to be of at least the same material yield strength;
- cut-outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates;
- where support is provided by gussets with shedder plates, the height of the gusset plate, see h_g in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6*, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100 per cent and 80 per cent, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. *See also Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*;
- scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

(j) In general, an upper stool is to be fitted in compliance with the following requirements:

    (i) General:

- where no upper stool is fitted, finite element analysis is to be carried out in accordance with the LR ShipRight Procedure for Ship Units to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure;
- side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission;
- brackets are to be arranged in the intersections between the upper stool and the structure on deck.

    (ii) Stool bottom plating:

- the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead, and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

    (iii) Stool side plating and internal structure:

- within the region of the corrugation depth above the stool bottom plate, the net thickness of the stool side plate is to be not less than 80 per cent of that required by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7* for the corrugated bulkhead flange at the upper end, where the same material is used. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors (k);
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than that required by *Pt 10, Ch 3, 2.6 Bulkheads 2.6.2*, *Pt 10, Ch 3, 2.6 Bulkheads 2.6.4* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.5* for the transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

(k) Where gussets with shedder plates, or shedder plates (slanting plates), are fitted at the end connection of the corrugation to the lower stool or the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.6.8 **Non-tight bulkheads.**

(a) Non-tight bulkheads (wash bulkheads) are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in the LR ShipRight Procedure for Ship Units. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10 per cent of the area of the bulkhead.

2.7 Primary support members

2.7.1 **General.**

(a) The scantlings of a primary support member are to comply with the minimum requirements of *Pt 10, Ch 3, 2.2 General 2.2.5*.

(b) The shear area of a primary support member is, in general, to comply with the requirements of *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* when idealised as a simple beam.

(c) The scantlings of all primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in the LR ShipRight Procedure for Ship Units.

(d) Primary support members are to be provided with adequate end fixity and in general be arranged in one plane to form continuous transverse rings.

(e) Primary support members are to have adequate lateral stability and the webs stiffened in accordance with buckling requirements from *Pt 10, Ch 1, 18 Buckling*.

(f) Primary support members that have open slots for stiffeners are to have a depth not less than 2,5 times the depth of the slots.

■ *Section 3*
Forward of the forward cargo tank

3.1 Symbols

3.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

B = moulded breadth, in metres

D = moulded depth, in metres

T_{SC} = deep load draught, in metres

T_{LT} = minimum design light load draught, in metres

E = modulus of elasticity, in N/mm^2

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

s = stiffener spacing, in mm

p = design pressure for the design load set being considered, in kN/m^2

g = acceleration due to gravity, 9,81 m/s^2

k = higher strength steel factor, defined in *Pt 10, Ch 1, 3.1 General 3.1.7*.

3.2 General

3.2.1 **Application.**

(a) The requirements of this Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0,1L of the unit's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of *Pt 10, Ch 3, 2 Cargo tank region*.

3.2.2 **General scantling requirements.**

(a) The deck plating thickness and supporting structure are to be suitably reinforced in way of deck machinery and topside units.

3.2.3 **Structural continuity.**

(a) Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. See also *Pt 10, Ch 3, 1.6 Tapering and structural continuity of longitudinal hull girder elements*.
(b) All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends.

3.2.4 **Minimum thickness.**

(a) In addition to the required scantlings given in this Section, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region given in *Pt 10, Ch 3, 2.2 General 2.2.4* and *Pt 10, Ch 3, 2.2 General 2.2.5*, except as given in *Pt 10, Ch 3, 3.2 General 3.2.4*.

Table 3.3.1 Minimum net thickness of structure forward of the forward cargo tank

Scantling location	Net thickness (mm)
Pillar bulkheads	7,5
Breasthooks	6,5
Floors and bottom girders	$5,5 + 0,02L_2$
Web plating of primary support members	$6,5 + 0,015L_2$

3.3 Bottom structure

3.3.1 **Plate keel.**

(a) A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.1*.

3.3.2 **Bottom shell plating.**

(a) The thickness of the bottom shell plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

3.3.3 **Bottom longitudinals.**

(a) Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.
(b) The section modulus and thickness of the bottom longitudinals are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

3.3.4 **Bottom floors.**

(a) Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is not to be less than the depth of the floors within the cargo tank region.

3.3.5 **Bottom girders.**

(a) A supporting structure is to be provided at the centreline, either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.
(b) Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that fitted in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.3.6 **Plate stems.**

(a) Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500 mm apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.
(b) Between the minimum design light draught, T_{LT}, at the stem and the deep load draught, T_{SC}, the plate stem net thickness, $t_{stem\text{-}net}$, is not to be less than:

$$t_{stem\text{-}net} = \frac{L_2\sqrt{\frac{235}{\sigma_{yd}}}}{12} \text{ mm, but need not be taken as greater than 21 mm}$$

Above the deep load draught, the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the minimum design light load draught, the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.3.7 **Floors and girders in spaces aft of the collision bulkhead.**

(a) Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank are to comply with the requirements in *Pt 10, Ch 3, 3.3 Bottom structure 3.3.4* and *Pt 10, Ch 3, 3.3 Bottom structure 3.3.5* and are to comply with the shear area requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.

3.4 Side structure

3.4.1 **Side shell plating.**

(a) The thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*. Where applicable, the thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*.
(b) Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.4.2 **Side shell local support members.**

(a) Longitudinal framing of the side shell is to be carried as far forward as practicable.
(b) The section modulus and thickness of the hull envelope framing are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.
(c) End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and, where not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.4.3 **Side shell primary support structure.**

(a) In general, the spacing of web frames, S, is to be taken as

S = 2,6 + 0,005L_2 m, but not to be taken greater than 3,5 m.
(b) In general, for the transverse framing forward of the collision bulkhead, stringers are to be spaced approximately 3,5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.
(c) Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.
(d) The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*, with the following additional requirements:

(i) Where no cross ties are fitted:

- the required section modulus of the web frame is to be maintained for 60 per cent of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20 per cent;
- the required shear area of the lower part of the web frame is to be maintained for 60 per cent of the shear span measured from the lower end.

(ii) Where one cross tie is fitted:

- the effective spans for bending and shear of a web frame or stringer are to be taken, ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50 per cent of the values that are calculated, ignoring the presence of the cross tie. For a web frame, the required section modulus and shear area of the lower part of the web frame are to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame are to be maintained for the section above the cross tie;
- cross ties are to be designed using the design loads specified in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

(iii) Configurations with multiple cross ties are to be specially considered, in accordance with *Pt 10, Ch 3, 3.4 Side structure 3.4.3*.
(iv) Where complex grillage structures are employed, the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

(e) The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

3.5 Deck structure

3.5.1 **Deck plating.**

(a) The thickness of the deck plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* with the applicable lateral pressure, green sea and deck loads.

3.5.2 **Deck stiffeners.**

(a) The section modulus and thickness of deck stiffeners are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*, with the applicable lateral pressure, green sea and deck loads.

3.5.3 **Deck primary support structure.**

(a) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.

(b) The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

(c) In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

3.5.4 **Pillars.**

(a) Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

(b) Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/ insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

(c) Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45 per cent of the specified minimum yield stress of the material.

(d) The scantlings of pillars are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.5*.

(e) Where the loads from heavy equipment exceed the design load of *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.5*, the pillar scantlings are to be determined based on the actual loading.

3.6 Tank bulkheads

3.6.1 **General.**

(a) Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.6.2 **Construction.**

(a) In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.6.3 **Scantlings of tank boundary bulkheads.**

(a) The thickness of tank boundary plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

(b) The section modulus and thickness of stiffeners are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

(c) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.

(d) Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.

(e) Scantlings of corrugated bulkheads are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.4*.

3.7 Watertight boundaries

3.7.1 **General.**

(a) Watertight boundaries are to be fitted in accordance with *Pt 4, Ch 3, 5 Number and disposition of bulkheads*.
(b) The number of openings in watertight bulkheads is to be kept to a minimum, compatible with the design and operation of the ship unit. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc. arrangements are to be made to maintain the watertight integrity.

3.7.2 **Scantlings of watertight boundaries.**

(a) The thickness of boundary plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.
(b) The section modulus and thickness of stiffeners are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.
(c) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.
(d) Web plating of primary support members is to have a depth of not less than 10 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.
(e) Scantlings of corrugated bulkheads are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.4*.

3.8 Superstructure

3.8.1 **Forecastle structure.**

(a) Forecastle structures are to be supported by girders with deep beams and web frames, and, in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3,5 m. Pillars are to be provided as required by *Pt 10, Ch 3, 3.5 Deck structure 3.5.4*. Main structural intersections are to be carefully developed, with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.9 Mooring systems

3.9.1 **Supporting structure.**

(a) Where the structure is subjected to concentrated mooring loads from mooring arms or yokes, external turrets or mooring hawsers, etc. the scantlings and arrangements are to be specially considered. Finite element analysis of attachments to the hull is to be carried out to ensure satisfactory stress distribution of the mooring loads into the hull structure. The permissible local stress levels are to comply with the LR ShipRight Procedure for Ship Units and *Pt 4, Ch 5 Primary Hull Strength*, as applicable.

3.10 Miscellaneous structures

3.10.1 **Pillar bulkheads.**

(a) Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports no less effective than required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of *Pt 10, Ch 3, 3.5 Deck structure 3.5.4*. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$, where t_{net} is the net thickness of plating, in mm.
(b) Pillar bulkheads are to comply with the following requirements:
  (i) the distance between bulkhead stiffeners is not to exceed 1500 mm;
  (ii) where corrugated, the depth of the corrugation is not to be less than 100 mm.

3.11 Scantling requirements

3.11.1 **General.**

(a) The design load sets are to be applied to the structural requirements for the local support and primary support members, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*. The static and dynamic load components are to be combined in accordance with *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7* and the procedure given in *Pt 10, Ch 2 Loads and Load Combinations*.

3.11.2 **Plating and local support members.**

(a) For plating subjected to lateral pressure, the net plating thickness, t_{net} , is to comply with the requirements of *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*, where C_a is taken as given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

Table 3.3.2 Permissible bending stress coefficient for plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0,80
AC2	Hull envelope plating	0,95
	Internal boundary plating	1,00
AC3	All plating	1,0

(b) For stiffeners subjected to lateral pressure, the net section modulus, Z_{net} , is to comply with the requirements of *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*, where C_s is taken as given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

Table 3.3.3 Permissible bending stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90
AC3	All stiffeners	1,0

(c) For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, $t_{w\text{-}net}$, is to comply with the requirements of *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* where C_t is taken as given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

Table 3.3.4 Permissible shear stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90
AC3	All stiffeners	1,0

3.11.3 **Primary support members.**

(a) For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, see *Pt 10, Ch 3, 3.4 Side structure 3.4.3*.

(b) For primary support members subjected to lateral pressure, the net section modulus, Z_{net50} , is to comply with *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* for all applicable design load sets in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

(c) For primary support members subjected to lateral pressure, the effective net shear area, $A_{shr\text{-}net50}$, is to comply with *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* for all applicable design load sets in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

(d) Primary support members are generally to be analysed with the specific methods described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3* when subjected to the applicable design load sets.

3.11.4 **Corrugated bulkheads.**

(a) Special consideration will be given to the approval of corrugated bulkheads, where fitted.

NOTE

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

3.11.5 **Pillars.**

(a) The maximum load on a pillar, W_{pill} , is to be taken as the greatest value calculated for all applicable design load sets, as given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{pill\text{-}perm}$ is based on the net properties of the pillar:

$W_{pill} \leq W_{pill\text{-}perm}$

where

W_{pill} = applied axial load on pillar

= $P\, b_{a\text{-}sup}\, l_{a\text{-}sup} + W_{pill\text{–}upr}$ kN

$W_{pill\text{-}perm}$ = permissible load on a pillar

= $0{,}1 A_{pill\text{-}net50}\, \eta_{pill}\, \sigma_{crb}$ kN

$b_{a\text{-}sup}$ = mean breadth of area supported, in metres

$l_{a\text{-}sup}$ = mean length of area supported, in metres

$W_{pill\text{–}upr}$ = axial load from pillar or pillars above, in kN

$A_{pill\text{-}net50}$ = net cross-sectional area of the pillar, in cm^2

η_{pill} = utilisation factor for the design load set being considered:

= 0,5 for acceptance criteria set AC1

= 0,6 for acceptance criteria set AC2

= 0,6 for acceptance criteria set AC3

σ_{crb} = critical buckling stress in compression of pillar based on the net sectional properties, in N/mm^2.

■ *Section 4*
Machinery space

4.1 Symbols

4.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

s = stiffener spacing, in mm.

4.2 General

4.2.1 **Application.**

(a) This Section prescribes scantling requirements for a machinery space or spaces located at any longitudinal frame location, such as a machinery space at the forward end. The requirements of this Section apply to all machinery spaces, regardless of location. For conventional self-propelled vessels, the requirements of *Pt 3, Ch 7 Machinery Spaces* of the Rules for Ships may also be used for guidance.

(b) Where a machinery space is permitted to overlap either of the regions defined in *Pt 10, Ch 3, 3 Forward of the forward cargo tank* and *Pt 10, Ch 3, 5 Aft end*, the most onerous of the design requirements for the machinery space and the overlapping region are to take precedence.

(c) Where a machinery space is located at a forward or aft region susceptible to local impact and slamming loads, the additional strengthening requirements prescribed in *Pt 10, Ch 3, 6 Evaluation of structure for sloshing and impact loads* are to be complied with in addition to the requirements in this Section.

4.2.2 **Arrangements.**

(a) All machinery and related systems are to be supported to distribute the loads into the structure of the ship unit. The adjacent structure is to be suitably stiffened.
(b) Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.
(c) The scantlings of the structure and the area of attachments are to consider the weight, power and proportions of the machinery, especially where the engines are positioned relatively high in proportion to the width of the bed plate.
(d) The foundations for main machinery and, where fitted, propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. It is recommended that plans of the above structure be submitted to the machinery manufacturer for review.
(e) A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump-room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.
(f) When main auxiliary machinery is fitted above the weather deck, the machinery is to be protected by deckhouses, in accordance with *Pt 10, Ch 1, 10.1 General 10.1.1*.

4.2.3 **Minimum thickness.**

(a) In addition to the requirements for thickness, section modulus and shear area, as given in *Pt 10, Ch 3, 4.3 Bottom structure* to *Pt 10, Ch 3, 4.9 Scantling requirements*, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements for the cargo region given in *Pt 10, Ch 3, 2.2 General 2.2.4* and *Pt 10, Ch 3, 2.2 General 2.2.5*, except as applicable in *Pt 10, Ch 3, 4.2 General 4.2.3*.

Table 3.4.1 Minimum net thickness of structure in the machinery space

Scantling location		Net thickness (mm)
Plating	Lower decks and flats	$3,3 + 0,0067s$
	Inner bottom	$6,5 + 0,02L_2$
Floors and bottom longitudinal girders off centreline		$5,5 + 0,02L_2$
Web plating of primary support members		$5,5 + 0,015L_2$

4.3 Bottom structure

4.3.1 **General**

(a) In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas, provided that the overall strength of the double bottom structure is not thereby impaired.

4.3.2 **Bottom shell plating.**

(a) The keel plate breadth is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.1*.
(b) The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*.

4.3.3 **Bottom shell stiffeners.**

(a) The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1* and *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*.

4.3.4 **Girders and floors.**

(a) The double bottom is to be arranged with a centreline girder.

(b) Full depth bottom girders are to be arranged in way of the main machinery to distribute its weight effectively and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and be suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.
(c) Where the bottom is transversely framed, plate floors are to be fitted at every frame.
(d) Where the bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.
(e) Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

4.3.5 **Inner bottom plating.**

(a) Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

4.3.6 **Sea chests**

(a) Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.4 Side structure

4.4.1 **General.**

(a) The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.
(b) A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.
(c) Stiffeners and primary support members are to be supported at their ends.

4.4.2 **Side shell plating.**

(a) The thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*. Where applicable, the thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*.

4.4.3 **Side shell local support members.**

(a) The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1* and*Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*.
(b) End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and, when not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.4.4 **Side shell primary support members.**

(a) Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.
(b) The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.
(c) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.2*.
(d) The web depth is to be not less than 2,5 times the web depth of the adjacent frames if the slots are not closed.
(e) Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending.

4.5 Deck structure

4.5.1 **General.**

(a) All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.
(b) The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.
(c) In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

(d) Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

(e) Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

(f) Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

(g) The structural scantlings are not to be less than the requirement for tank boundaries if the deck forms the boundary of a tank.

(h) The structural scantlings are not to be less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.5.2 **Deck scantlings.**

(a) The plate thickness of deck plating is to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*.

(b) The section modulus and thickness of deck stiffeners are to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1* and *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.1*.

(c) The web depth of deck stiffeners is to be not less than 60 mm.

(d) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 4.9 Scantling requirements 4.9.2*.

(e) The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

(f) In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.5.3 **Pillars.**

(a) Pillars are to comply with the requirements of *Pt 10, Ch 3, 3.5 Deck structure 3.5.4*.

(b) In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

4.6 Machinery foundations

4.6.1 **General.**

(a) Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of sufficient strength to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

(b) In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to increase substantially the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case, and the thrust bearing.

(c) For ship units with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed.

4.6.2 **Foundations for internal combustion engines and thrust bearings.**

(a) In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

(b) Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

NOTE

In general, the gross thickness of foundation top plates is not to be less than 45 mm, where the maximum continuous output of the propulsion machinery is 3500 kW or greater.

4.6.3 **Auxiliary foundations.**

(a) Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

4.7 Tank bulkheads

4.7.1 **General.**

(a) Tanks are to comply with the requirements of *Pt 10, Ch 3, 3.6 Tank bulkheads*, with scantlings determined using the factors from *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1* and *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*.

Table 3.4.2 Permissible bending stress coefficient for plating

Acceptance criteria set	Structural member		β_a	α_a	C_{a-max}
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0
AC3	All members		1,0	0	1,0

The permissible bending stress coefficient, C_a , for the design load set being considered is to be taken as:

C_a = $\beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

= $\dfrac{(z - z_{NA-net50}) M_{v-total}}{I_{v-net50}} 10^{-3}$ N/mm^2

$M_{v-total}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv} , see Table 2.6.1 in Chapter 2

$I_{v-net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA-net50}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.4.3 Permissible bending stress coefficient for stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side that pressure is acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{s-max}
Compression (–ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (–ve)	Stiffener side	

where

β_s, α_s, $C_{s\text{-}max}$ = permissible bending stress factors and are to be taken as:

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinally effective stiffeners	0,85	1,0	0,75
	Other stiffeners	0,75	0	0,75
AC2	Longitudinally effective stiffeners	1,0	1,0	0,9
	Other stiffeners	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9
AC3	All members	1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$$= \frac{(z - z_{NA-net50})M_{v-total}}{I_{v-net50}}10^{-3} \text{ N/mm}^2$$

$M_{v\text{-}total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm $M_{v\text{-}total}$ is to be calculated in accordance with *Pt 10, Ch 2, 6.1 Symbols 6.1.1* in *Pt 10, Ch 2 Loads and Load Combinations* using the sagging or hogging still water bending moment

Stiffener location	$M_{sw\text{-}perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Hogging SWBM

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

z = vertical coordinate of the reference point, in metres

$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

4.8 Watertight boundaries

4.8.1 General.

(a) Watertight boundaries are to comply with the requirements of *Pt 10, Ch 3, 3.7 Watertight boundaries*, with scantlings determined using the factors from *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1* and *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*.

4.9 Scantling requirements

4.9.1 Plating and local support members.

(a) For plating subjected to lateral pressure, the net plating thickness is to comply with the requirements of *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*, where C_a is taken as given in *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*.

(b) For stiffeners subjected to lateral pressure, the net section modulus requirement is to comply with the requirements of *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*, where C_s is taken as defined in *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*.

(c) For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements is to comply with the requirements of *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*, where C_t is taken as given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* in the previous Section.

4.9.2 Primary support members.

(a) For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.
(b) For primary support members subjected to lateral pressure, the net section modulus requirement is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.
(c) For primary support members subjected to lateral pressure, the net cross-sectional area of the web is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.
(d) Primary support members are generally to be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level, for all primary support members are less than permissible stresses and stress coefficients given in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*, when subjected to the applicable design load sets.

4.9.3 **Corrugated bulkheads.**

(a) Special consideration will be given to the approval of corrugated bulkheads, where fitted.

NOTE

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see *Pt 10, Ch 3, 2.6 Bulkheads 2.6.6* and *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*.

4.9.4 **Pillars.**

(a) The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.5*.

■ *Section 5* Aft end

5.1 Symbols

5.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

s = stiffener spacing, in mm.

5.2 General

5.2.1 **Application.**

(a) The requirements of this Section apply to structure located between the aft peak bulkhead and the aft end of the ship unit.
(b) The requirements of this Section do not apply to the following:
   (i) rudder horns;
   (ii) structures which are not integral with the hull, such as rudders, steering nozzles and propellers;
   (iii) other appendages permanently attached to the hull. Where such items are fitted, the relevant requirements of the Rules for Ships are to be complied with.
(c) The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery.

5.2.2 **Structural continuity.**

(a) Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. *See also Pt 10, Ch 3, 1.6 Tapering and structural continuity of longitudinal hull girder elements*.
(b) Longitudinal framing of the strength deck is to be carried aft to the stern.
(c) All shell frames and tank boundary stiffeners are, in general, to be continuous or bracketed at their ends.

5.2.3 **Minimum thickness.**

(a) In addition to the scantling requirements as given in *Pt 10, Ch 3, 5.3 Bottom structure* to *Pt 10, Ch 3, 5.8 Miscellaneous structures*, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region, except as given in *Pt 10, Ch 3, 5.2 General 5.2.3*.

Table 3.5.1 Minimum net thickness of structure aft of the aft peak bulkhead

Scantling location	Net thickness (mm)
Pillar bulkhead plating	7,5
Bottom girders and aft peak floors	$5,5 + 0,02L_2$
Web plating of primary support members	$6,5 + 0,015L_2$

5.3 Bottom structure

5.3.1 General.

(a) Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube, where fitted. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.

(b) The centreline bottom girder is to extend as far aft as is practicable and be suitably scarphed into the stern frame or transom.

(c) For self-propelled units with conventional propulsion and steering arrangements, the relevant Sections of the Rules for Ships are to be complied with.

5.4 Shell structure

5.4.1 Shell plating.

(a) The net thickness of the side shell and transom plating, t_{net} , is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

(b) The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and is not to be less than:

$t_{net} = 0,094\ (L_2 – 43) + 0,009s$ mm.

(c) In way of the boss and heel plate, the shell net plating thickness, t_{net} , is not to be less than:

$t_{net} = 0,105\ (L_2 – 47) + 0,011s$ mm.

(d) Within the extents specified in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*, the thickness of the side shell plating is to comply with the requirements in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.4*.

5.4.2 Shell local support members.

(a) The section modulus and thickness of the hull envelope framing are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

5.4.3 Shell primary support members.

(a) The requirements of *Pt 10, Ch 3, 5.4 Shell structure 5.4.3* apply to single side skin construction supported by a system of vertical webs and/or horizontal stringers or flats.

(b) Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

(c) Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

(d) The scantlings of web frames supporting longitudinal framing, stringers and transverse framing are to be determined from *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.

(e) The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

5.5 Deck structure

5.5.1 Deck plating.

(a) The thickness of the deck plating is to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

5.5.2 **Deck stiffeners.**

(a) The section modulus and thickness of deck stiffeners are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* and *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*.

5.5.3 **Deck primary support members.**

(a) The section modulus and shear area of primary support members are to comply with the requirements in *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.3*.

(b) The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

(c) In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

5.5.4 **Pillars.**

(a) Pillars are to comply with the requirements of *Pt 10, Ch 3, 3.5 Deck structure 3.5.4*.

5.6 Tank bulkheads

5.6.1 **General.**

(a) Tanks are to comply with the requirements of *Pt 10, Ch 3, 3.6 Tank bulkheads*.

5.7 Watertight boundaries

5.7.1 **General.**

(a) Watertight boundaries are to comply with the requirements of *Pt 10, Ch 3, 3.7 Watertight boundaries*.

5.7.2 **Aft peak bulkhead.**

(a) The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in *Pt 10, Ch 3, 3.6 Tank bulkheads* and *Pt 10, Ch 3, 3.7 Watertight boundaries 3.7.2*, as applicable.

5.8 Miscellaneous structures

5.8.1 **Pillar bulkheads.**

(a) Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports no less effective than those required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of *Pt 10, Ch 3, 5.5 Deck structure 5.5.4*. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$ of the plating, where t_{net} is net plating thickness, in mm.

(b) Pillar bulkheads are to meet the following requirements:

   (i) the distance between bulkhead stiffeners is not to exceed 1500 mm;
   (ii) where corrugated, the depth of the corrugation is not to be less than 100 mm.

5.8.2 **Rudder trunk.**

(a) Where a rudder trunk is fitted, the scantlings are to be in accordance with the shell plating and framing in *Pt 10, Ch 3, 5.4 Shell structure 5.4.1* and *Pt 10, Ch 3, 5.4 Shell structure 5.4.2*. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.8.3 **Stern thruster tunnels.**

(a) The net thickness of the tunnel plating, $t_{tun\text{-}net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun\text{-}net}$ is not to be taken less than:

$t_{tun\text{-}net} = 0{,}008d_{tun} + 1{,}8$ m

where

d_{tun} = inside diameter of tunnel, in mm, but not to be taken less than 970 mm.

(b) Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

Section 6
Evaluation of structure for sloshing and impact loads

6.1 Symbols

6.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

B = moulded breadth, in metres

D = moulded depth, in metres

C_b = block coefficient

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

τ_{yd} = $\frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

s = stiffener spacing, in mm

P = design pressure for the design load set being considered, in N/mm^2

6.2 General

6.2.1 **Application.**

(a) The requirements of this Section cover the additional strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads in the forward and aft structure. The impact loads to be applied in *Pt 10, Ch 3, 6.4 Bottom slamming* are described in *Pt 10, Ch 2, 4 Sloshing and impact loads*.

6.3 Sloshing in tanks

6.3.1 **Scope and limitations.**

(a) The requirements of the LR ShipRight Procedure for Ship Units specify the methodology in assessing the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, due to the free movement of liquid in tanks.
(b) The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, is to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.
(c) All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.
(d) The following structural members are to be assessed:
   (i) plates and stiffeners forming boundaries of tanks;
   (ii) plates and stiffeners on wash bulkheads;
   (iii) web plates and web stiffeners of primary support members located in tanks;
   (iv) tripping brackets supporting primary support members in tanks.

6.4 Bottom slamming

6.4.1 **Application.**

(a) Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in *Pt 10, Ch 2 Loads and Load Combinations*, is less than 0,045*L*, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

(b) For self-propelling units with conventional single screw, ship-type aft sections, additional strengthening against aft slamming will not normally be required. For units with full deep aft sections, strengthening to resist bottom slamming should be applied over 0,3*L* aft, using the requirements of *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.3* and *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.4* and the applicable draughts aft. Units with raised or unusual sections aft that may be susceptible to slamming will be specially considered, using the requirements of *Pt 4, Ch 2, 4.3 Strengthening for wave impact loads* and *Pt 4, Ch 2, 5.2 Strengthening for wave impact loads*of the Rules for Ships.

(c) The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, see *Pt 10, Ch 3, 1.2 Loading guidance*.

(d) The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross-sectional shear areas of primary support members are to be applied as required by *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7* and *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.

(e) For harsh service, special consideration should be given to strengthening of bottom forward in relation to the actual forces determined from model tests and/or direct calculations.

6.4.2 **Extent of strengthening.**

(a) The strengthening is to extend forward of 0,3*L* from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.2*.

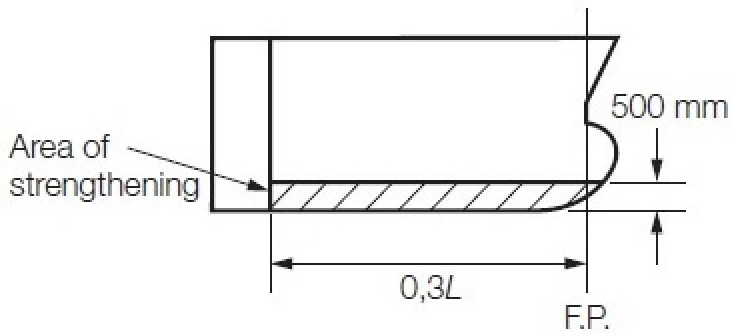


Figure 3.6.1 Extent of strengthening against bottom slamming

(b) Outside the region strengthened to resist bottom slamming, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 **Design to resist bottom slamming loads.**

(a) The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl-net}}{f_{bdg}} \text{ cm}^3$$

where

$Z_{pl\text{-}net}$ = net plastic section modulus, in cm^3, as required by *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.5*

f_{bdg} = bending moment factor

= $8\left(1 - \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1 for one end equivalent to built in and one end simply supported.

(b) Scantlings and arrangements at primary support members, including bulkheads, are to comply with *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.

6.4.4 **Hull envelope plating.**

(a) The net thickness of the hull envelope plating, t_{net} , is not to be less than:

$$t_{net} = \frac{0,0158\,\alpha_p s}{C_q}\sqrt{\frac{P_{slm}}{C_a \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

= $1,2 - \frac{s}{2100 l_p}$ but not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing between primary support members or panel breakers, in metres

P_{slm} = bottom slamming pressure as given in *Pt 10, Ch 2, 4.2 Bottom slamming loads 4.2.2* and calculated at the load calculation point, in kN/m^2

Cd = plate capacity correction coefficient

= 1,3

Ca = permissible bending stress coefficient

= 1,0 for acceptance criteria set AC3.

6.4.5 **Hull envelope stiffeners.**

(a) The net plastic section modulus, $Z_{pl\text{-}net}$, of each individual stiffener, is not to be less than:

$$Z_{pl\text{-}net} = \frac{P_{slm} s l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

= $8\left(1 + \frac{n_s}{2}\right)$

n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, see *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.3* for alternative arrangements

C_s = permissible bending stress coefficient

= 0,9 for acceptance criteria set AC3.

(b) The net web thickness, $t_{w\text{-}net}$, of each longitudinal is not to be less than:

$t_{w\text{-}net}$ = $\dfrac{P_{slm} s l_{shr}}{2 d_{shr} C_t \tau_{yd}}$ mm

where

l_{shr} = effective shear span, in metres

d_{shr} = effective web depth of stiffener, in mm

C_t = permissible shear stress coefficient

= 1,0 for acceptance criteria set AC3.

6.4.6 **Definition of idealised bottom slamming load area for primary support members.**

(a) The scantlings of items in *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7* are based on the application of the slamming pressure defined in *Pt 10, Ch 2 Loads and Load Combinations* to an idealised area of hull envelope plating, the slamming load area, A_{slm} , given by:

A_{slm} = $\dfrac{1,1 L B C_b}{1000}$ m^2

6.4.7 **Primary support members.**

(a) The size and number of openings in web plating of the floors and girders are to be minimised, considering the required shear area as given in *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.

(b) The net shear area, $A_{shr\text{-}net50}$, of each primary support member web at any position along its span is not to be less than:

$A_{shr\text{-}net50}$ = $10 \dfrac{Q_{slm}}{C_t \tau_{yd}}$ cm^2

where

Q_{slm} = the greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{slm} , to the most onerous location, as determined in accordance with *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*

C_t = permissible shear stress coefficient

= 0,9 for acceptance criteria set AC3.

(c) For simple arrangements of primary support members, where the grillage effect may be ignored, the shear force, Q_{slm} , is given by:

Q_{slm} = $f_{pt} f_{dist} F_{slm}$ kN

where

f_{pt} = correction factor for the proportion of patch load acting on a single primary support member

= $0,5 (f_{slm}^{\ 3} - 2f_{slm}^{\ 2} + 2)$

f_{slm} = patch load modification factor

= $0,5 \dfrac{b_{slm}}{S}$, but not to be greater than 1,0

f_{dist} = factor for the greatest shear force distribution along the span, see *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*

F_{slm} = $P_{slm} l_{slm} b_{slm}$

l_{slm} = extent of slamming load area along the span

= $\sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

l_{shr} = effective shear span, in metres

b_{slm} = breadth of impact area supported by primary support member

= $\sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} = as defined in *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.6*

S = primary support member spacing, in metres.

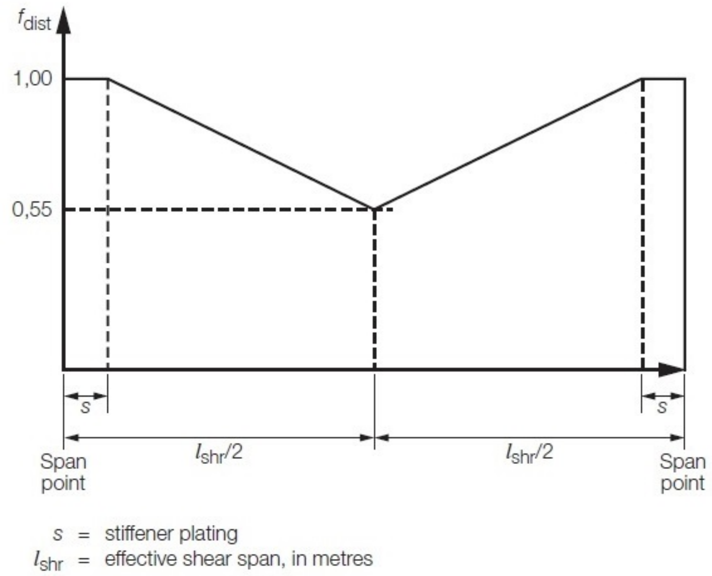


Figure 3.6.2 Distribution of fdist along the span of simple primary support members

(d) For complex arrangements of primary support members, the greatest shear force, Q_{slm} , at any location along the span of each primary support member is to be derived by direct calculation in accordance with *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.

Table 3.6.1 Direct calculation methods for derivation of Qslm

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model
NOTE The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, *see Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.		

(e) The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w\text{-}net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

where

s_w = plate breadth, in mm, taken as the spacing between the web stiffening.

6.4.8 **Connection of longitudinals to primary support members.**

(a) Longitudinals are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.

(b) The scantlings in way of the end connections of each longitudinal are to comply with the requirements of *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members*.

6.5 Bow impact

6.5.1 **Application.**

(a) The side structure in the area forward of 0,1*L* from the FP is to be strengthened against bow impact pressures.

(b) The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross-sectional areas of the primary support member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.7*.

6.5.2 **Extent of strengthening.**

(a) The strengthening is to extend forward of 0,1*L* from the FP and vertically above the minimum design light load draught, T_{LT} , see *Pt 10, Ch 3, 6.5 Bow impact 6.5.2*.

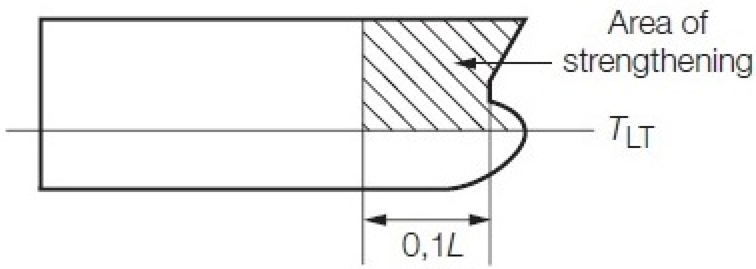


Figure 3.6.3 Extent of strengthening against bow impact

(b) Outside the strengthening region, as given in *Pt 10, Ch 3, 6.5 Bow impact 6.5.2*, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.5.3 **Design to resist bow impact loads.**

(a) In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

(b) The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl-net}}{f_{bdg}} \text{ cm}^3$$

where

$Z_{pl\text{-}net}$ = effective net plastic section modulus, required by *Pt 10, Ch 3, 6.5 Bow impact 6.5.5*, in cm^3

f_{bdg} = bending moment factor

= $8\left(1+\frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1,0 for one end equivalent to built-in and one end simply supported.

(c) Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with *Pt 10, Ch 3, 6.5 Bow impact 6.5.7*. In areas of greatest bow impact load, the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections are, in general, to be applied.

(d) The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.5.4 **Side shell plating.**

(a) The net thickness of the side shell plating, t_{net} , is not to be less than:

$$t_{net} = 0,0158\,\alpha_p s\sqrt{\frac{P_{im}}{C_a\sigma_{yd}}}$$

where

α_p = correction factor for the panel aspect ratio

= $1,2-\frac{s}{2100 l_p}$ but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing between the primary support members, or panel breakers, in metres

P_{im} = bow impact pressure as given in *Pt 10, Ch 2, 4.3 Bow impact loads 4.3.2* and calculated at the load calculation point, in kN/m^2

C_a = permissible bending stress coefficient

= 1,0 for acceptance criteria set AC3.

6.5.5 **Side shell stiffeners.**

(a) The effective net plastic section modulus, $Z_{pl\text{-}net}$, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl\text{-}net} = \frac{P_{im} s l_{bdg}{}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

l_{lbdg} = effective bending span, in metres

f_{bdg} = bending moment factor

= $8\left(1+\frac{n_s}{2}\right)$

n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, see *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.3* for alternative arrangements

C_s = permissible bending stress coefficient

= 0,9 for acceptance criteria set AC3.

(b) The net web thickness, $t_{w\text{-}net}$, of each stiffener is not to be less than:

$$t_{w\text{-}net} = \frac{P_{im} s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \text{ mm}$$

where

l_{shr} = effective shear span, in metres

d_{shr} = effective web depth of stiffener, in mm

= permissible shear stress coefficient

= 1,0 for acceptance criteria set AC3.

(c) The minimum net thickness of breasthooks/ diaphragm plates, $t_{w\text{-}net}$, is not to be less than:

$$t_{w\text{-}net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

where

s = spacing of stiffeners on the web, in mm. Where no stiffeners are fitted, s is to be taken as the depth of the web.

6.5.6 **Definition of idealised bow impact load area for primary support members.**

(a) The scantlings of items in *Pt 10, Ch 3, 6.5 Bow impact 6.5.7* are based on the application of the bow impact pressure to an idealised area of hull envelope plating, where the bow impact load area, A_{slm} , is given by:

$$A_{slm} = \frac{1,1 L B C_b}{1000} \text{ m}^2$$

6.5.7 **Primary support members.**

(a) Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

(b) To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

S = 3 + 0,008L_2 m.

(c) End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

(d) Tripping brackets are to be fitted where the primary support member flange is knuckled or curved. The torsional buckling mode of primary support members is to be controlled by flange supports or tripping brackets. The un - supported length of the flange of the primary support member, i.e. the distance between tripping brackets, s_{bkt} , is not to be greater than:

$$s_{bkt} = b_f C \sqrt{\frac{235}{\sigma_{yd}} \frac{A_{f-net50}}{\left(A_{f-net50} + \frac{A_{w-net50}}{30}\right)}} \text{ m, but need not be less than } s_{bkt\text{-}min}$$

where

b_f = breadth of flange, in mm

C = slenderness coefficient:

= 0,022 for symmetrical flanges

= 0,033 for one-sided flanges

$A_{f\text{-}net50}$ = net cross-sectional area of flange, in cm^2

$A_{w\text{-}net50}$ = net cross-sectional area of the web plate, in cm^2

$s_{bkt\text{-}min}$ = 4,0 m.

(e) The net section modulus of each primary support member, Z_{net50} , is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg-pt} P_{im} b_{slm} f_{slm} l_{bdg}{}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

$f_{bdg\text{-}pt}$ = correction factor for the bending moment at the ends and considering the patch load

= $3f_{slm}{}^3 - 8f_{slm}{}^2 + 6f_{slm}$

f_{slm} = patch load modification factor

= $\dfrac{l_{slm}}{l_{slm}}$

l_{slm} = extent of bow impact load area along the span

= $\sqrt{A_{slm}}$ m, but not to be taken as greater than l_{bdg}

A_{slm} = bow impact load area, in m^2, as defined in *Pt 10, Ch 3, 6.4 Bottom slamming 6.4.6*

l_{bdg} = effective bending span, in metres

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not to be taken as greater than l_{slm} , in metres

f_{bdg} = bending moment factor

= 12 for primary support members with end fixed continuous face-plates, stiffeners or where stiffeners are bracketed at both ends

C_s = permissible bending stress coefficient

= 0,8 for acceptance criteria set AC3.

(f) The net shear area of the web, $A_{shr\text{-}net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{shr\text{-}net50} = \frac{5 f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \text{ cm}^2$$

where

f_{pt} = patch load modification factor

= $\dfrac{l_{slm}}{l_{shr}}$

l_{slm} = extent of bow impact load area along the span

= $\sqrt{A_{slm}}$ m,

but not to be taken as greater than l_{shr}

l_{shr} = effective shear span, in metres

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm} , in metres

C_t = permissible shear stress coefficient

= 0,75 for acceptance criteria set AC3.

(g) The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell, is not to be less than:

$$t_{w\text{-}net} = \frac{P_{im} b_{slm}}{\sin \varphi_w \sigma_{crb}} \text{ mm}$$

where

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm} , in metres

ϕ_w = angle, in degrees, between the primary support member web and the shell plate

σ_{crb} = critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load, in N/mm^2.

6.5.8 **Connection of stiffeners to primary support members.**

(a) Stiffeners are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.
(b) The scantlings of the end connection of each stiffener are to comply with the requirements of *Pt 10, Ch 3, 1.10 Intersections of continuous local support members and primary support members*.

■ *Section 7*

Application of scantling requirements to other structure

7.1 Symbols

7.1.1 The symbols used in this Chapter are defined as follows:

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

s = stiffener spacing, in mm

S = primary support member spacing, in metres

F = point load for the design load set being considered, in kN

P = design pressure for the design load set being considered, in kN/m^2.

7.2 General

7.2.1 **Application.**

(a) The requirements of this Section apply to plating, local and primary support members where the basic structural configurations or strength models assumed in *Pt 10, Ch 3, 2 Cargo tank region* to *Pt 10, Ch 3, 5 Aft end* are not appropriate. These are general-purpose strength requirements to cover various load assumptions and end support conditions.
(b) The requirements for local and primary support members are to be specially considered when the member is:
   (i) part of a grillage structure;

(ii) subject to large relative deflection between end supports;

(iii) where the load model or end support condition is not given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*.

(c) The application of alternative or more advanced calculation methods will be specially considered.

7.3 Scantling requirements

7.3.1 General.

(a) The design load sets to be applied to the structural requirements for the local and primary support members are given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with *Pt 10, Ch 2, 6.1 Symbols 6.1.1* and the requirements given in *Pt 10, Ch 2 Loads and Load Combinations*.

7.3.2 Plating and local support members.

(a) For plating subjected to lateral pressure, the net thickness, t_{net} , is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{net} = 0,0158\,\alpha_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1,2 - \dfrac{s}{2100 l_p}$

l_p = length of plate panel, to be taken as the spacing of primary support members, *S*, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered, as given in *Pt 10, Ch 3, 2.3 Hull envelope plating 2.3.2*, *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* or *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*, as applicable for the individual member being considered.

(b) For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net} , is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net} = \frac{|P| s l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3\text{, for lateral pressure loads}$$

$$Z_{net} = \frac{1000 |F| l_{bdg}}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3\text{, for point loads}$$

$$Z_{net} = \frac{\left| \sum \frac{P_i s l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j l_{bdg}}{f_{bdg-i}} \right|}{C_s \sigma_{yd}} \text{ cm}^3\text{, for a combination of loads}$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

= 12 for horizontal stiffeners

= 10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

C_s = permissible bending stress coefficient for the design load set being considered as given in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2*, *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2* or *Pt 10, Ch 3, 4.7 Tank bulkheads 4.7.1*, as applicable for the individual member being considered

I = indices for load component i

j = indices for load component j.

(c) For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, $t_{w\text{-}net}$, based on shear area requirements is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{w\text{-}net} = \frac{f_{shr}|P|sl_{shr}}{d_{shr}C_t\tau_{yd}} \text{ mm, for lateral pressure loads}$$

$$t_{w\text{-}net} = \frac{1000f_{shr}|F|}{d_{shr}C_t\tau_{yd}} \text{ mm, for point loads}$$

$$t_{w\text{-}net} = \frac{\left|\sum f_{shr-i}P_isl_{shr} + \sum 1000f_{shr-j}F_j\right|}{d_{shr}C_t\tau_{yd}} \text{ mm, for a combination of loads}$$

where

f_{shr} = shear force factor

for continuous stiffeners with end connections consistent with the idealisation of the stiffener as having fixed ends:

= 0,5 for horizontal stiffeners

= 0,7 for vertical stiffeners

for other configurations the shear force factor may be taken as in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

l_{shr} = effective shear span, in metres

d_{shr} = effective shear depth, in mm

C_t = permissible shear stress coefficient for design load set, as given in *Pt 10, Ch 3, 2.4 Hull envelope framing 2.4.2* or *Pt 10, Ch 3, 3.11 Scantling requirements 3.11.2*, for the individual member being considered

I = indices for load component i

j = indices for load component j.

7.3.3 **Primary support members.**

(a) The requirements in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* and *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*, when subjected to the applicable design load sets. *See also* 7.1.1.4.

(b) The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross-sectional shear areas of the primary support member are to be applied as required in the notes of *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*.

(c) For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

(d) For primary support members, the net section modulus requirement, Z_{net50} , is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net50} = \frac{1000|P|S l_{bdg}^{2}}{f_{bdg} C_{s-pr} \sigma_{yd}} \text{ cm}^3\text{, for lateral pressure loads}$$

$$Z_{net50} = \frac{1000|F|S l_{bdg}}{f_{bdg} C_{s-pr} \sigma_{yd}} \text{ cm}^3\text{, for point loads}$$

$$Z_{net50} = \frac{\left| \Sigma \dfrac{1000 P_i S l_{bdg}^{2}}{f_{bdg-i}} + \dfrac{1000 F_j l_{bdg}}{f_{bdg-j}} \right|}{C_{s-pr} \sigma_{yd}} \text{ cm}^3\text{, for a combination of loads}$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor, as given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

C_{s-pr} = permissible bending stress coefficient as given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* for design load set given in , for the individual member being considered

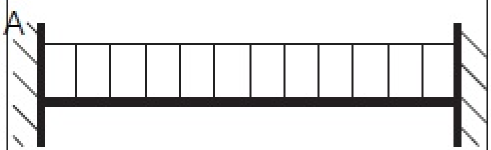
I = indices for load component i

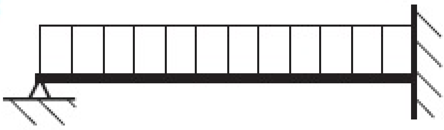
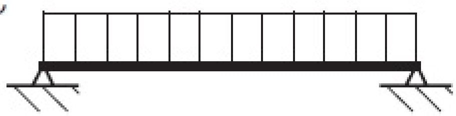
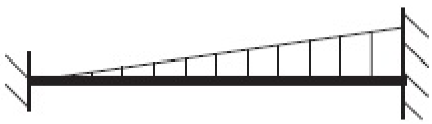
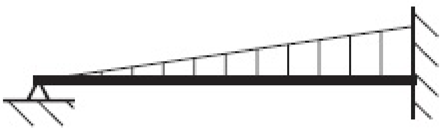
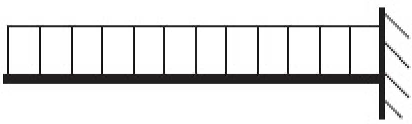
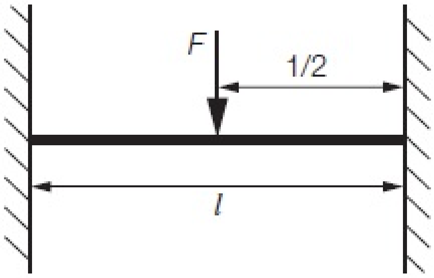
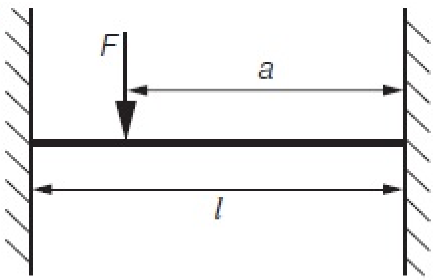
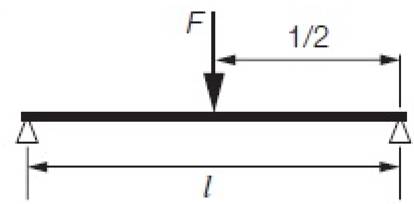
j = indices for load component j.

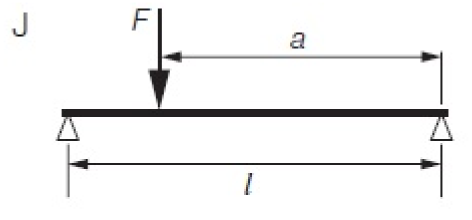
Table 3.7.1 Permissible stress coefficients, Cs-pr for primary support members

Acceptance criteria set	Permissible bending stress coefficient, Cs-pr	Permissible shear stress coefficient, Ct-pr
AC1	0,70	0,70
AC2	0,85	0,85
AC3	0,9	0,9

Table 3.7.2 Values of fbdg and fshr

Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model		Position, *see Note* 1		1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
				12,0 0,50	24,0 -	12,0 0,50	Built-in at both ends Uniform pressure distribution

	B 	– 0,38	14,2 –	8,0 0,63	Built-in at one end plus simply supported one end Uniform pressure distribution
	C 	– 0,50	8,0 –	– 0,50	Simply supported, (both ends are free to rotate) Uniform pressure distribution
	D 	15,0 0,30	23,3 –	10,0 0,70	Built-in at both ends Linearly varying pressure distribution
	E 	– 0,20	16,8 –	7,5 0,80	Built-in at one end plus simply supported one end Linearly varying pressure distribution
	F 	– –	– –	2,0 1,0	Cantilevered beam Uniform pressure distribution
	G 	8,0 0,5	8,0 –	8,0 0,5	Built-in at both ends Single point load in the centre of the span
	H 	$\frac{l^3}{a^2(l-a)}$ $\frac{a^2(3l-2a)}{l^3}$	$\frac{l^4}{2a^2(l-a)^2}$ –	$\frac{l^3}{a(l-a)^2}$ $\frac{(l-a)^2(l+2a)}{l^3}$	Built-in at both ends Single point load, with load anywhere in the span
	I 	– 0,5	4 –	– 0,5	Simply supported Single point load in the centre of the span

		–	$\dfrac{l^2}{a(l-a)}$	–	Simply supported Single point load, load anywhere along the span

Symbols

l = effective span, l_{bdg} and l_{shr} , as applicable

l_{bdg} = effective span in bending, for local or primary support members, in metres

l_{shr} = effective span in shear, for local or primary support members, in metres

NOTES

1. The bending moment factor, f_{bdg} , for the support positions is applicable for a distance of $0,2l_{bdg}$ from the end of the effective bending span for both local and primary support members.

2. The shear force factor, f_{shr} , for the support positions is applicable for a distance of $0,2l_{shr}$ from the end of the effective shear span for both local and primary support members.

3. Application of f_{bdg} and f_{shr} for local support members:

(a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1} , f_{bdg2} and f_{bdg3} ;

(b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3} .

4. Application of f_{bdg} and f_{shr} for primary support members:

(a) the section modulus requirement within $0,2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3} ; however, f_{bdg} is not to be taken greater than 12;

(b) the section modulus of mid span area is to be determined using f_{bdg} = 24, or f_{bdg2} from the Table if lesser;

(c) the shear area requirement of end connections within $0,2l_{shr}$ from the end of the effective span is to be determined using f_{shr} = 0,5 or the applicable f_{shr1} or f_{shr3} , whichever is greater;

(d) for models A to F, the value of f_{shr} may be gradually reduced outside of $0,2l_{shr}$ towards $0,5f_{shr}$ at mid span, where f_{shr} is the greater value of f_{shr1} and f_{shr3} .

(e) For primary support members, the net shear area of the web, $A_{shr\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, and given by:

$$A_{shr\text{-}net50} = \frac{10 f_{shr} |P| S l_{shr}}{C_{t-pr}\,\tau_{yd}} \text{ cm}^2\text{, for lateral pressure loads}$$

$$A_{shr\text{-}net50} = \frac{10 f_{shr} |F|}{C_{t-pr}\,\tau_{yd}} \text{ cm}^2\text{, for point loads}$$

$$A_{shr\text{-}net50} = \frac{\left|\sum 10 f_{shr-i} P_i s l_{shr} + \sum 10 f_{shr-j} F_j\right|}{C_{t-pr}\,\tau_{yd}} \text{ cm}^2\text{, for a combination of loads}$$

where

l_{shr} = effective shear span, in metres

f_{shr} = shear force factor, as given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3*

$C_{t\text{-}pr}$ = permissible shear stress coefficient as given in *Pt 10, Ch 3, 7.3 Scantling requirements 7.3.3* for design load set given in *Pt 10, Ch 3, 2.6 Bulkheads 2.6.7*, for the individual member being considered

I = indices for load component i

j = indices for load component j.

Section 1
General

1.1 Application

1.1.1 This Appendix contains Dynamic Load Combination Factor (DLCF) Tables for:

- scantling assessment;
- strength assessment by FEM;

as specified in *Pt 10, Ch 2, 7.1 Dynamic load cases and dynamic load combination factors for strength assessment* and *Pt 10, Ch 2, 8.1 Site-specific dynamic load combination factors*. An index to the Tables is given in *Table 4.1.1 Index to Dynamic Load Combination Factor Tables for initial design*

The symbols are as defined in *Pt 10, Ch 2, 6.1 Symbols* and as follows:

f_{mv} = dynamic load combination factor for vertical wave bending moment

f_{mh} = dynamic load combination factor for horizontal wave bending moment

$f_{v\text{-}mid}$ = dynamic load combination factor for the vertical acceleration of a centre tank

$f_{v\text{-}pt}$ = dynamic load combination factor for the vertical acceleration of a port tank

$f_{v\text{-}stb}$ = dynamic load combination factor for the vertical acceleration of a starboard tank

f_t = dynamic load combination factor for the transverse acceleration of a centre tank

$f_{lng\text{-}mid}$ = dynamic load combination factor for the longitudinal acceleration of a centre tank

$f_{lng\text{-}pt}$ = dynamic load combination factor for the longitudinal acceleration of a port tank

$f_{lng\text{-}stb}$ = dynamic load combination factor for the longitudinal acceleration of a starboard tank

$f_{lng\text{-}ctr}$ = dynamic load combination factor for the longitudinal acceleration of a centre double bottom tank

$f_{ctr\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at centreline, starboard side

$f_{bilge\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at bilge, starboard side

$f_{WL\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at still waterline, starboard side

$f_{ctr\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at centreline, port side

$f_{bilge\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at bilge, port side

$f_{WL\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at still waterline, port side

Table 4.1.1 Index to Dynamic Load Combination Factor Tables for initial design

Unit size and operating condition	Environment *see* Note 1	Scantling assessment				Strength assessment by FEM
		Draught	Aft end region	Central tank region	Forward end region	
Aframax or VLCC Transit	Unrestricted	Deep	*Table 4.1.2 Dynamic load cases for aft end region for deep draught condition, unrestricted worldwide transit*	*Table 4.1.3 Dynamic load cases for central tank region for deep draught condition, unrestricted worldwide transit*	*Table 4.1.4 Dynamic load cases for forward end region for deep draught condition, unrestricted worldwide transit*	*Table 4.1.50 Dynamic load cases for strength assessment (by FEM), unrestricted worldwide transit*
	worldwide	Light	*Table 4.1.5 Dynamic load cases for aft end region for light draught condition, unrestricted worldwide transit*	*Table 4.1.6 Dynamic load cases for central tank region for light draught condition, unrestricted worldwide transit*	*Table 4.1.7 Dynamic load cases for forward end region for light draught condition, unrestricted worldwide transit*	
Aframax Weather vaning	West of Shetland Is.	Deep	*Table 4.1.8 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.*	*Table 4.1.9 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.*	*Table 4.1.10 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.*	*Table 4.1.51 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, west of Shetland Is.*
		Light	*Table 4.1.11 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, west of Shetland Is.*	*Table 4.1.12 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, west of Shetland Is.*	*Table 4.1.13 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, west of Shetland Is.*	
Aframax Weather vaning	North Sea	Deep	*Table 4.1.14 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, North Sea*	*Table 4.1.15 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, North Sea*	*Table 4.1.16 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, North Sea*	*Table 4.1.52 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, North Sea*

		Light	*Table 4.1.17 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, North Sea*	*Table 4.1.18 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea*	*Table 4.1.19 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea*	
Aframax Weather vaning	Brazil Campos Basin	Deep	*Table 4.1.20 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin*	*Table 4.1.21 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Brazil Campos*	*Table 4.1.22 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin*	*Table 4.1.53 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Brazil*
		Light	*Table 4.1.23 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin*	*Table 4.1.24 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin*	*Table 4.1.25 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin*	
Aframax Weather vaning	Western Australia (non-cyclonic)	Deep	*Table 4.1.26 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.27 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.28 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.54 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Western Australia (non-cyclonic)*
		Light	*Table 4.1.29 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.30 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.31 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	

VLCC Weather vaning	Brazil Campos Basin	Deep	*Table 4.1.32 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin*	*Table 4.1.33 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)*	*Table 4.1.34 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin*	*Table 4.1.55 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Brazil ampos Basin*
		Light	*Table 4.1.35 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin*	*Table 4.1.36 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Campos Basin*	*Table 4.1.37 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin*	
VLCC Weather vaning	Western Australia (non-cyclonic)	Deep	*Table 4.1.38 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	*Table 4.1.39 Dynamic load cases for central tank region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	*Table 4.1.40 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	*Table 4.1.56 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Western Australia (non-cyclonic)*
		Light	*Table 4.1.41 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	*Table 4.1.42 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	*Table 4.1.43 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)*	
VLCC Spread moored	Nigeria	Deep	*Table 4.1.44 Dynamic load cases for aft end region for deep draught condition for a spread moored VLCC unit Nigeria*	*Table 4.1.45 Dynamic load cases for central tank region for deep draught condition for a spread moored VLCC unit Nigeria*	*Table 4.1.46 Dynamic load cases for forward end region for deep draught condition for a spread moored VLCC unit, Nigeria*	*Table 4.1.57 Dynamic load cases for strength assessment by FEM for a spread moored VLCC unit, Nigeria*

		Light	*Table 4.1.47 Dynamic load cases for aft end region for light draught condition for a spread moored VLCC unit, Nigeria*	*Table 4.1.48 Dynamic load cases for central tank region for light draught condition for a spread moored VLCC unit, Nigeria*	*Table 4.1.49 Dynamic load cases for forward end region for light draught condition for a spread moored VLCC unit, Nigeria*	

NOTE

The geographic locations of the sites at which long-term environmental data has been used to derive the DLCF Tables are shown in *Table 2.3.2 Environmental factors*.

Table 4.1.2 Dynamic load cases for aft end region for deep draught condition, unrestricted worldwide transit

Wave direction	Following sea	Oblique sea		Beam sea			
Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	–0,7	–0,7	–0,4	–0,4	–0,1	–0,1
$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,4
$f_{v\text{-}stb}$	0,6	0,9	—	1,0	—	0,4	—
f_t	0,0	0,2	–0,2	0,5	–0,5	1,0	–1,0
f_{lng}	0,8	0,7	0,7	0,6	0,6	–0,1	–0,1
f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2
f_{WL}	0,5	1,0	0,2	0,8	0,3	0,5	–0,3
f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2
f_{WL}	0,5	0,2	1,0	0,3	0,8	–0,3	0,5

Table 4.1.3 Dynamic load cases for central tank region for deep draught condition, unrestricted worldwide transit

Wave direction	Head sea		Beam sea					
Max. response	M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	0,3	0,3
f_{mh}	0,0	0,0	–0,1	0,1	0,0	0,0	0,0	0,0
$f_{v\text{-}mid}$	–0,2	0,5	0,5	0,5	1,0	1,0	1,0	1,0
$f_{v\text{-}pt}$	–0,2	0,5	0,2	0,6	0,8	1,0	0,8	1,0
$f_{v\text{-}stb}$	–0,2	0,5	0,6	0,2	1,0	0,8	1,0	0,8
f_t	0,0	0,0	1,0	–1,0	0,5	–0,5	0,6	–0,6
$f_{lng\text{-}mid}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{lng\text{-}pt}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{lng\text{-}stb}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6

$f_{lng\text{-}ctr}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{ctr\text{-}stb}$	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,3	–0,2	0,8	–0,3	0,9	0,4	1,0	0,4
$f_{WL\text{-}stb}$	0,3	–0,3	0,5	–0,2	0,8	0,4	1,0	0,4
$f_{ctr\text{-}pt}$	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,3	–0,2	–0,3	0,8	0,4	0,9	0,4	1,0
$f_{WL\text{-}pt}$	0,3	–0,3	–0,2	0,5	0,4	0,8	0,4	1,0

Table 4.1.4 Dynamic load cases for forward end region for deep draught condition, unrestricted worldwide transit

Wave direction	Head sea		Oblique sea				Beam Sea	
Max. response	a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	–0,7	0,9	–0,3	–0,3	–0,4	–0,4	–0,4	–0,4
f_{mh}	0,0	0,0	0,1	–0,1	0,2	–0,2	–0,1	0,1
$f_{v\text{-}mid}$	0,7	–0,6	0,9	0,9	0,7	0,7	1,0	1,0
$f_{v\text{-}pt}$	0,7	–0,6	0,9	1,0	0,7	0,7	0,9	1,0
$f_{v\text{-}stb}$	0,7	–0,6	1,0	0,9	0,7	0,7	1,0	0,9
f_t	0,0	0,0	0,7	–0,7	0,7	0,7	0,6	–0,6
$f_{lng\text{-}mid}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
$f_{lng\text{-}pt}$	–0,8	1,0	–0,5	–0,5	–1,0	–0,7	–0,5	–0,5
$f_{lng\text{-}stb}$	–0,8	1,0	–0,5	–0,5	–0,7	–1,0	–0,5	–0,5
$f_{lng\text{-}ctr}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
$f_{ctr\text{-}stb}$	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
$f_{bilge\text{-}stb}$	0,6	–0,7	1,0	0,5	0,7	0,3	1,0	0,5
$f_{WL\text{-}stb}$	0,3	–0,5	0,9	0,8	1,0	0,2	0,9	0,4
$f_{ctr\text{-}pt}$	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
$f_{bilge\text{-}pt}$	0,6	–0,7	0,5	1,0	0,3	0,7	0,5	1,0
$f_{WL\text{-}pt}$	0,3	–0,5	0,4	0,9	0,2	1,0	0,4	0,9

Table 4.1.5 Dynamic load cases for aft end region for light draught condition, unrestricted worldwide transit

Location	Aft end region						
Wave direction	Following sea	Oblique sea		Beam sea			
Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	–0,3	–0,3	0,2	0,2	0,1	0,1
$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,5

$f_{v\text{-}stb}$	0,6	0,9	–	1,0	–	0,5	–
f_t	0,0	0,1	–0,1	0,6	–0,6	1,0	–1,0
f_{lng}	0,7	0,8	0,8	0,2	0,2	0,0	0,0
f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1
f_{WL}	0,8	1,0	0,3	0,6	0,1	0,4	–0,3
f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1
f_{WL}	0,8	0,3	1,0	0,1	0,6	–0,3	0,4

Table 4.1.6 Dynamic load cases for central tank region for light draught condition, unrestricted worldwide transit

Wave direction	Head sea		Beam sea					
Max. response	M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	–0,2	–0,2
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,2	0,2
$f_{v\text{-}mid}$	–0,1	0,4	0,5	0,5	1,0	1,0	1,0	1,0
$f_{v\text{-}pt}$	–0,1	0,4	0,1	0,8	0,7	1,0	0,6	1,0
$f_{v\text{-}stb}$	–0,1	0,4	0,8	0,1	1,0	0,7	1,0	0,6
f_t	0,0	0,0	1,0	–1,0	0,8	–0,8	0,6	–0,6
$f_{lng\text{-}mid}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}pt}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}stb}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{ctr\text{-}stb}$	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
$f_{bilge\text{-}stb}$	0,3	–0,2	0,9	–0,4	0,9	0,3	0,9	0,2
$f_{WL\text{-}stb}$	0,3	–0,2	0,7	–0,4	0,9	0,2	1,0	0,2
$f_{ctr\text{-}pt}$	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
$f_{bilge\text{-}pt}$	0,3	–0,2	–0,4	0,9	0,3	0,9	0,2	0,9
f_{WL}	0,3	–0,2	–0,4	0,7	0,2	0,9	0,2	1,0

Table 4.1.7 Dynamic load cases for forward end region for light draught condition, unrestricted worldwide transit

Wave direction	Head sea		Oblique sea				Beam Sea	
Max. response	a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	–0,8	0,9	–0,2	–0,2	–0,3	–0,3	–0,1	–0,1
f_{mh}	0,0	0,0	–0,5	0,5	0,3	–0,3	–0,4	0,4
$f_{v\text{-}mid}$	0,7	–0,6	0,6	0,6	0,9	0,9	1,0	1,0
$f_{v\text{-}pt}$	0,7	–0,6	0,3	0,8	0,7	0,7	0,5	1,0

$f_{v\text{-}stb}$	0,7	–0,6	0,8	0,3	0,7	0,7	1,0	0,5
f_t	0,0	0,0	0,9	–0,9	0,2	–0,2	0,7	–0,7
$f_{lng\text{-}mid}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
$f_{lng\text{-}pt}$	–0,9	1,0	–0,5	0,2	–0,9	–0,6	0,0	0,0
$f_{lng\text{-}stb}$	–0,9	1,0	0,2	–0,5	–0,6	–0,9	0,0	0,0
$f_{lng\text{-}ctr}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
$f_{ctr\text{-}stb}$	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
$f_{bilge\text{-}stb}$	0,5	–0,4	1,0	–0,3	0,9	0,2	0,8	0,2
$f_{WL\text{-}stb}$	0,3	–0,2	0,9	–0,3	1,0	0,1	0,8	0,2
$f_{ctr\text{-}pt}$	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
$f_{bilge\text{-}pt}$	0,5	–0,4	–0,3	1,0	0,2	0,9	0,2	0,8
$f_{WL\text{-}pt}$	0,3	–0,2	–0,3	0,9	0,1	1,0	0,2	0,8

Table 4.1.8 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,5	–0,2	–0,2	0,5	0,5	0,1	0,1
f_{mh}	–0,7	0,3	–0,3	0,7	–0,7	0,3	–0,3
$f_{v\text{-}mid}$	–1,0	–0,3	–0,3	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–1,0	–0,3	–0,3	1,0	1,0	0,1	0,3
$f_{v\text{-}stb}$	–1,0	–0,3	–0,3	1,0	1,0	0,3	0,1
f_t	0,2	0,0	0,0	–0,2	0,2	1,0	–1,0
$f_{lng\text{-}mid}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}pt}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}stb}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}ctr}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,5	0,5	–1,0	–1,0	–0,3	–0,3
$f_{bilge\text{-}stb}$	1,0	0,5	0,7	–0,9	–0,7	–0,8	0,4
$f_{WL\text{-}stb}$	0,7	1,0	1,0	–0,7	—0,4	–0,4	0,4
$f_{ctr\text{-}pt}$	1,0	0,5	0,5	–1,0	–1,0	–0,3	–0,3
$f_{bilge\text{-}pt}$	1,0	0,7	0,5	–0,7	–0,9	0,4	–0,8
$f_{WL\text{-}pt}$	0,7	1,0	1,0	–0,4	–0,7	0,4	—0,6

Table 4.1.9 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	0,8	0,8	–0,2	–0,2
f_{mh}	0,5	0,2	0,3	–1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
$f_{v\text{-}mid}$	0,5	1,0	–0,6	–0,1	–0,1	0,3	0,3	0,1	0,1	–0,1	–0,1
$f_{v\text{-}pt}$	0,5	1,0	–0,6	–0,1	–0,1	0,1	0,5	0,1	0,1	–0,1	–0,1
$f_{v\text{-}stb}$	0,5	1,0	–0,6	–0,1	–0,1	0,5	0,1	0,1	0,1	–0,1	–0,1
f_t	0,0	0,2	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}pt}$	–0,6	0,1	1,0	0,4	0,4	–0,1	0,1	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}stb}$	–0,6	0,1	1,0	0,4	0,4	0,1	–0,1	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}ctr}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
$f_{ctr\text{-}stb}$	1,0	–1,0	–0,2	–0,3	–0,3	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}stb}$	0,5	–1,0	–0,1	–0,4	0,1	–1,0	0,6	0,7	0,6	0,4	0,4
$f_{WL\text{-}stb}$	0,8	–0,7	–0,2	–0,3	0,1	–0,8	0,7	1,0	0,9	0,9	1,0
$f_{ctr\text{-}pt}$	1,0	–1,0	–0,2	–0,3	–0,3	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}pt}$	0,5	–1,0	–0,1	0,1	–0,4	0,6	–1,0	0,6	0,7	0,4	0,4
$f_{WL\text{-}pt}$	0,8	–0,7	–0,2	0,1	–0,3	0,7	–0,8	0,9	1,0	1,0	0,9

Table 4.1.10 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,7	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
f_{mh}	0,1	0,0	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	–0,1
f_t	0,1	0,0	0,0	0,0	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	0,8	0,9	0,8	1,0	1,0	0,8	0,8	–0,5	0,4

f_{WL-stb}	–0,5	0,5	0,8	0,7	0,7	0,8	1,0	1,0	–0,5	0,4
f_{ctr-pt}	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge-pt}$	–1,0	0,8	0,8	0,9	1,0	1,0	0,8	0,8	0,4	–0,5
f_{WL-pt}	–0,5	0,5	0,7	0,8	0,8	0,7	1,0	1,0	0,4	–0,5

Table 4.1.11 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,1	–0,1	–0,1	0,4	0,4	0,3	0,3
f_{mh}	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
f_{v-mid}	–0,5	–0,3	–0,3	1,0	1,0	0,5	0,5
f_{v-pt}	–0,5	–0,3	–0,3	1,0	1,0	0,4	0,6
f_{v-stb}	–0,5	–0,3	–0,3	1,0	1,0	0,6	0,4
f_t	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng-mid}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
f_{lng-pt}	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{lng-stb}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{lng-ctr}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{ctr-stb}$	1,0	0,5	0,5	–0,4	–0,4	–0,8	–0,8
$f_{bilge-stb}$	1,0	0,5	0,5	–0,1	–0,1	–0,9	0,5
f_{WL-stb}	1,0	1,0	1,0	0,1	0,1	–0,8	0,6
f_{ctr-pt}	1,0	0,5	0,5	–0,4	–0,4	–0,8	–0,8
$f_{bilge-pt}$	1,0	0,5	0,5	–0,1	–0,1	0,5	–0,9
f_{WL-pt}	1,0	1,0	1,0	0,1	0,1	0,6	–0,8

Table 4.1.12 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,4	–0,4	–0,4	0,2	0,2	0,8	0,8	0,5	0,5
f_{mh}	–0,6	0,0	0,0	–1,0	1,0	–0,8	0,8	0,0	0,0	0,0	0,0
f_{v-mid}	0,3	1,0	–0,5	–0,5	–0,5	0,3	0,3	0,1	0,1	–0,5	–0,5
f_{v-pt}	0,3	1,0	–0,5	–0,5	–0,5	0,1	0,5	0,1	0,1	–0,5	–0,5
f_{v-stb}	0,3	1,0	–0,5	–0,5	–0,5	0,5	0,1	0,1	0,1	–0,5	–0,5
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng-mid}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3

$f_{lng\text{-}pt}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{lng\text{-}stb}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{lng\text{-}ctr}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{ctr\text{-}stb}$	1,0	–0,4	–0,4	–0,4	–0,4	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,6	–0,5	–0,2	–0,6	0,2	–0,7	0,7	0,7	0,6	0,7	0,8
$f_{WL\text{-}stb}$	0,8	–0,9	–0,1	–0,2	0,3	–0,5	0,7	0,8	0,8	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,4	–0,4	–0,4	–0,4	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,6	–0,5	–0,2	0,2	–0,6	0,7	–0,7	0,6	0,7	0,8	0,7
$f_{WL\text{-}pt}$	0,8	–0,9	–0,1	0,3	–0,2	0,7	–0,5	0,8	0,8	1,0	1,0

Table 4.1.13 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,8	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	–0,8	0,8
f_{mh}	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,1	–0,1
f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge\text{-}stb}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	–0,7	0,6
$f_{WL\text{-}stb}$	–0,5	0,4	0,7	0,8	1,0	0,9	1,0	1,0	–0,6	0,5
$f_{ctr\text{-}pt}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge\text{-}pt}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	0,6	–0,7
$f_{WL\text{-}pt}$	–0,5	0,4	0,8	0,7	0,9	1,0	1,0	1,0	0,5	–0,6

Table 4.1.14 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,4	–0,2	–0,2	0,3	0,3	0,1	0,1
f_{mh}	–0,1	–0,3	0,3	–0,3	0,3	–0,1	0,1
$f_{v\text{-}mid}$	–0,1	–0,1	–0,1	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–0,1	–0,1	–0,1	1,0	1,0	0,1	0,3

f_{v-stb}	–0,1	–0,1	–0,1	1,0	1,0	0,3	0,1
f_{t}	0,0	0,0	0,0	0,1	–0,1	1,0	–0,1
$f_{lng-mid}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
f_{lng-pt}	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{lng-stb}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{lng-ctr}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{ctr-stb}$	1,0	0,7	0,7	–1,0	–1,0	–0,3	–0,3
$f_{bilge-stb}$	0,9	0,6	0,6	–0,9	–0,7	–0,7	0,5
f_{WL-stb}	0,7	1,0	1,0	–0,7	–0,3	–0,5	0,5
f_{ctr-pt}	1,0	0,7	0,7	–1,0	–1,0	–0,3	–0,3
$f_{bilge-pt}$	0,9	0,6	0,6	–0,7	–0,9	0,5	–0,7
f_{WL-pt}	0,7	1,0	1,0	–0,3	–0,7	0,5	–0,5

Table 4.1.15 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response	M_{wv}	a_{v}	a_{lng}	M_{wv-h}		a_{t}		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,3	–0,6	–0,3	–0,3	0,1	0,1	0,6	0,6	–0,2	–0,2
f_{mh}	–0,3	–0,1	–0,3	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
f_{v-mid}	0,7	1,0	–0,8	–0,3	–0,3	0,3	0,3	0,1	0,1	–0,2	–0,2
f_{v-pt}	0,7	1,0	–0,8	–0,3	–0,3	0,1	0,4	0,1	0,1	–0,2	–0,2
f_{v-stb}	0,7	1,0	–0,8	–0,3	–0,3	0,4	0,1	0,1	0,1	–0,2	–0,2
f_{t}	0,1	0,3	0,1	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng-mid}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
f_{lng-pt}	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{lng-stb}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{lng-ctr}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{ctr-stb}$	1,0	–0,9	–0,2	–0,2	–0,2	–0,4	–0,4	1,0	1,0	0,4	0,4
$f_{bilge-stb}$	0,6	–0,9	–0,1	–0,3	0,2	–0,9	0,8	0,6	0,7	0,5	0,5
f_{WL-stb}	0,8	–0,5	–0,2	–0,2	0,1	–0,6	0,6	0,8	0,9	1,0	1,0
f_{ctr-pt}	1,0	–0,9	–0,2	–0,2	–0,2	–0,4	–0,4	1,0	1,0	0,4	0,4
$f_{bilge-pt}$	0,6	–0,9	–0,1	0,2	–0,3	0,8	–0,9	0,7	0,6	0,5	0,5
f_{WL-pt}	0,8	–0,5	–0,2	0,1	–0,2	0,6	–0,6	0,9	0,8	1,0	1,0

Table 4.1.16 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	0,1
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,1	–0,1
f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	–0,4	0,4
$f_{WL\text{-}stb}$	–0,8	0,8	1,0	0,9	1,0	0,9	1,0	1,0	–0,4	0,4
$f_{ctr\text{-}pt}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,4	–0,4
$f_{WL\text{-}pt}$	–0,8	0,8	0,9	1,0	0,9	1,0	1,0	1,0	0,4	–0,4

Table 4.1.17 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,2	0,1	0,1	0,5	0,5	0,1	0,1
f_{mh}	–0,2	–0,1	0,1	–0,2	0,2	–0,8	0,8
$f_{v\text{-}mid}$	0,1	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,1	–0,4	–0,4	1,0	1,0	0,1	0,4
$f_{v\text{-}stb}$	0,1	–0,4	–0,4	1,0	1,0	0,4	0,1
f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–0,1
$f_{lng\text{-}mid}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}pt}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}stb}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}ctr}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	0,4	0,4	–0,6	–0,6	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	0,6	0,3	–0,1	–0,2	–0,8	0,8
$f_{WL\text{-}stb}$	–1,0	1,0	0,8	0,1	–0,1	–0,8	0,8

$f_{ctr\text{-}pt}$	–1,0	0,4	0,4	–0,6	–0,6	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	0,3	0,6	–0,2	–0,1	0,8	–0,8
$f_{WL\text{-}pt}$	–1,0	0,8	1,0	–0,1	0,1	0,8	–0,8

Table 4.1.18 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,5	–0,7	–0,7	0,1	0,1	0,7	0,7	0,4	0,4
f_{mh}	–0,2	–0,8	0,6	–1,0	1,0	–0,8	0,8	–0,2	0,2	–0,2	0,2
$f_{v\text{-}mid}$	0,2	1,0	–0,4	–0,9	–0,9	0,3	0,3	–0,1	–0,1	–0,6	–0,6
$f_{v\text{-}pt}$	0,2	1,0	–0,4	–0,9	–0,9	0,1	0,5	–0,1	–0,1	–0,6	–0,6
$f_{v\text{-}stb}$	0,2	1,0	–0,4	–0,9	–0,9	0,5	0,1	–0,1	–0,1	–0,6	–0,6
f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}pt}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}stb}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}ctr}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{ctr\text{-}stb}$	1,0	–0,1	–0,5	–0,7	–0,7	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,6	–0,6	–0,4	–0,7	0,2	–0,8	0,8	0,7	0,4	0,7	0,5
$f_{WL\text{-}stb}$	0,8	–1,0	–0,3	–0,2	0,4	–0,8	0,8	0,7	0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,1	–0,5	–0,7	–0,7	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,6	–0,6	–0,4	0,2	–0,7	0,8	–0,8	0,4	0,7	0,5	0,7
$f_{WL\text{-}pt}$	0,8	–1,0	–0,3	0,4	–0,2	0,8	–0,8	0,7	0,7	1,0	1,0

Table 4.1.19 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
f_{mh}	0,1	0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	–0,1	0,2
$f_{v\text{-}stb}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,2	0,1
f_t	–0,1	0,1	0,1	–0,1	0,1	–0,1	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1

$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}stb}$	–0,9	0,8	0,9	0,5	1,0	1,0	0,8	0,4	–0,8	0,7
$f_{WL\text{-}stb}$	–0,6	0,6	0,9	0,5	0,5	0,9	1,0	0,7	–0,8	0,7
$f_{ctr\text{-}pt}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}pt}$	–0,9	0,8	0,5	0,9	1,0	1,0	0,4	0,8	0,7	–0,8
$f_{WL\text{-}pt}$	–0,6	0,6	0,5	0,9	0,9	0,5	0,7	1,0	0,7	–0,8

Table 4.1.20 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,4	–0,1	–0,1	0,4	0,4	0,2	0,2
f_{mh}	–0,4	–0,1	0,1	–0,4	0,4	–0,1	0,1
$f_{v\text{-}mid}$	–1,0	0,1	0,1	1,0	1,0	0,4	0,4
$f_{v\text{-}pt}$	–1,0	0,1	0,1	1,0	1,0	0,2	0,5
$f_{v\text{-}stb}$	–1,0	0,1	0,1	1,0	1,0	0,5	0,2
f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}pt}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}stb}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}ctr}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,2	0,2	–1,0	–1,0	0,0	0,0
$f_{bilge\text{-}stb}$	0,6	0,2	0,2	–0,6	–0,6	–0,8	0,7
$f_{WL\text{-}stb}$	0,5	1,0	1,0	–0,4	–0,3	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	0,2	0,2	–1,0	–1,0	0,0	0,0
$f_{bilge\text{-}pt}$	0,6	0,2	0,2	–0,6	–0,6	0,7	–0,8
$f_{WL\text{-}pt}$	0,3	1,0	1,0	–0,3	–0,4	0,7	–0,7

Table 4.1.21 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Brazil Campos

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	–0,4	–0,4	–0,3	–0,3
f_{mh}	–0,4	0,2	0,7	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,5	1,0	–0,5	–0,1	–0,1	0,4	0,4	–1,0	–1,0	–0,2	–0,2

$f_{v\text{-}pt}$	0,5	1,0	–0,5	–0,1	–0,1	0,1	0,6	–1,0	–1,0	–0,2	–0,2
$f_{v\text{-}stb}$	0,5	1,0	–0,5	0,1	–0,1	0,6	0,1	–1,0	–1,0	–0,2	–0,2
f_t	0,1	0,2	–0,1	0,1	–0,1	1,0	–1,0	0,2	–0,2	0,0	0,0
$f_{lng\text{-}mid}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}pt}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}stb}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}ctr}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{ctr\text{-}stb}$	0,7	–0,9	–0,2	–0,2	–0,2	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,3	–0,6	–0,1	–0,2	0,1	–0,9	0,9	0,6	0,5	0,3	0,3
$f_{WL\text{-}stb}$	0,6	–0,5	0,2	–0,2	0,1	–0,9	0,9	0,5	0,2	1,0	1,0
$f_{ctr\text{-}pt}$	0,7	–0,9	–0,2	–0,2	–0,2	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,3	–0,6	–0,1	0,1	–0,2	0,9	–0,9	0,5	0,6	0,3	0,3
$f_{WL\text{-}pt}$	0,6	–0,5	0,2	0,1	–0,2	0,9	–0,9	0,2	0,5	1,0	1,0

Table 4.1.22 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,2
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,2	–0,1
f_t	0,0	0,0	0,1	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0
$f_{bilge\text{-}stb}$	–0,9	0,9	0,9	0,9	1,0	1,0	0,8	0,9	–0,7	0,7
$f_{WL\text{-}stb}$	–0,8	0,8	0,9	0,7	0,9	0,9	1,0	1,0	–0,7	0,7
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0
$f_{bilge\text{-}pt}$	–0,9	0,9	0,9	0,9	1,0	1,0	0,9	0,8	0,7	–0,7
$f_{WL\text{-}pt}$	–0,8	0,8	0,7	0,9	0,9	0,9	1,0	1,0	0,7	–0,7

Table 4.1.23 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,2	–0,3	–0,3	–0,2	–0,2	–0,1	–0,1
f_{mh}	–0,1	–0,1	0,1	–0,2	0,2	–0,8	0,8
$f_{v\text{-}mid}$	0,4	–0,5	–0,5	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	0,4	–0,5	–0,5	1,0	1,0	–0,1	0,4
$f_{v\text{-}stb}$	0,4	–0,5	–0,5	1,0	1,0	0,4	–0,1
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}pt}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}stb}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	–0,7	–0,7	0,0	0,0
$f_{bilge\text{-}stb}$	–0,5	0,5	0,5	–0,4	–0,4	0,8	–0,8
$f_{WL\text{-}stb}$	–0,7	1,0	1,0	–0,3	–0,1	0,8	–0,8
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	–0,7	–0,7	0,0	0,0
$f_{bilge\text{-}pt}$	–0,5	0,5	0,5	–0,4	–0,4	0,8	–0,8
$f_{WL\text{-}pt}$	–0,7	1,0	1,0	–0,1	–0,3	0,8	–0,8

Table 4.1.24 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	–0,1	–0,5	–0,8	–0,8	–0,1	–0,1	0,7	0,7	0,5	0,5
f_{mh}	–0,1	–0,1	–0,2	–1,0	1,0	–0,8	0,8	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,1	1,0	–0,3	–0,5	–0,5	0,2	0,2	–0,1	–0,1	–0,5	–0,5
$f_{v\text{-}pt}$	0,1	1,0	–0,3	–0,5	–0,5	–0,1	0,5	–0,1	–0,1	–0,5	–0,5
$f_{v\text{-}stb}$	0,1	1,0	–0,3	–0,5	–0,5	0,5	–0,1	–0,1	–0,1	–0,5	–0,5
f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}pt}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}stb}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}ctr}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{ctr\text{-}stb}$	1,0	–0,7	–0,5	–0,9	–0,9	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,3	–0,4	–0,2	–0,6	0,2	–0,8	0,8	0,4	0,4	0,6	0,6

$f_{WL\text{-}stb}$	0,5	–0,3	–0,1	–0,4	0,4	–0,8	0,8	0,5	0,5	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,7	–0,5	–0,9	–0,9	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,3	–0,4	–0,2	0,2	–0,6	0,8	–0,8	0,4	0,4	0,6	0,6
$f_{WL\text{-}pt}$	0,5	–0,3	–0,1	0,4	–0,4	0,8	–0,8	0,5	0,5	1,0	1,0

Table 4.1.25 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,6	–0,6	–0,1	–0,1
f_{mh}	–0,1	–0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,2	0,2
$f_{v\text{-}pt}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	–0,1	0,4
$f_{v\text{-}stb}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,4	–0,1
f_t	0,1	0,1	0,1	–0,1	0,1	0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,0	0,0
$f_{bilge\text{-}stb}$	–0,5	0,4	0,5	0,4	1,0	0,6	0,5	0,5	–0,8	0,8
$f_{WL\text{-}stb}$	–0,4	0,3	0,5	0,4	1,0	0,6	1,0	0,8	–0,8	0,8
$f_{ctr\text{-}pt}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,0	0,0
$f_{bilge\text{-}pt}$	–0,5	0,4	0,4	0,5	0,6	1,0	0,5	0,5	0,8	–0,8
$f_{WL\text{-}pt}$	–0,4	0,3	0,4	0,5	0,6	1,0	0,8	1,0	0,8	–0,8

Table 4.1.26 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	–0,3	–0,3	0,5	0,5	0,2	0,2
f_{mh}	–0,1	–0,9	–0,9	–0,5	0,5	0,0	0,0
$f_{v\text{-}mid}$	0,4	–0,2	–0,2	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,4	–0,2	–0,2	1,0	1,0	0,2	0,4
$f_{v\text{-}stb}$	0,4	–0,2	–0,2	1,0	1,0	0,4	0,2
f_t	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1

$f_{lng\text{-}stb}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,6	0,6	–0,9	–0,9	–0,4	–0,4
$f_{bilge\text{-}stb}$	–0,1	0,6	0,3	–0,7	–0,7	–0,6	0,5
$f_{WL\text{-}stb}$	–0,2	1,0	0,9	–0,5	–0,2	–0,5	0,5
$f_{ctr\text{-}pt}$	1,0	0,6	–0,6	–0,9	–0,9	–0,4	–0,4
$f_{bilge\text{-}pt}$	–0,1	0,3	0,6	–0,7	–0,7	0,5	–0,6
$f_{WL\text{-}pt}$	–0,2	0,9	1,0	–0,2	–0,5	0,5	–0,5

Table 4.1.27 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,8	–0,5	–0,4	–0,4	0,2	0,2	–0,5	–0,5	–0,3	–0,3
f_{mh}	–0,1	–0,1	–0,5	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,2	0,2
$f_{v\text{-}mid}$	0,4	1,0	–0,3	–0,2	–0,2	0,3	0,3	–1,0	–1,0	–0,1	–0,1
$f_{v\text{-}pt}$	0,4	1,0	–0,3	–0,2	–0,2	0,1	0,4	–1,0	–1,0	–0,1	–0,1
$f_{v\text{-}stb}$	0,4	1,0	–0,3	–0,2	–0,2	0,4	0,1	–1,0	–1,0	–0,1	–0,1
f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,3	–0,3	0,0	0,0
$f_{lng\text{-}mid}$	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
$f_{lng\text{-}pt}$	–0,3	0,4	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
$f_{lng\text{-}stb}$	–0,3	0,2	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
$f_{lng\text{-}ctr}$	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
$f_{ctr\text{-}stb}$	0,4	–0,8	–0,2	–0,2	–0,2	–0,3	–0,3	1,0	1,0	0,2	0,2
$f_{bilge\text{-}stb}$	0,2	–0,6	–0,2	–0,3	0,2	–0,8	0,8	0,8	0,7	0,5	0,2
$f_{WL\text{-}stb}$	0,4	–0,3	–0,2	–0,3	0,1	–0,7	0,7	0,7	0,3	1,0	1,0
$f_{ctr\text{-}pt}$	0,4	–0,8	–0,2	–0,2	–0,2	–0,3	–0,3	1,0	1,0	0,2	0,2
$f_{bilge\text{-}pt}$	0,2	–0,6	–0,2	0,2	–0,3	0,8	–0,8	0,7	0,8	0,2	0,5
$f_{WL\text{-}pt}$	0,4	–0,3	–0,2	0,1	–0,3	0,7	–0,7	0,3	0,7	1,0	1,0

Table 4.1.28 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,8	–0,8	–0,9	–0,9	–1,0	–1,0	–0,4	–0,4	0,1	0,1
f_{mh}	–0,1	–0,1	–0,1	–1,0	–0,1	0,1	–0,3	–0,3	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,0	0,0

$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,1	–0,1
f_t	0,1	0,1	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	0,9	1,0	0,7	1,0	1,0	0,3	0,3	–0,5	0,5
$f_{WL\text{-}stb}$	–0,4	0,4	0,3	0,5	0,5	0,6	1,0	0,6	–0,5	0,4
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	0,9	0,7	1,0	1,0	1,0	0,3	0,3	0,5	–0,5
$f_{WL\text{-}pt}$	–0,4	0,4	0,5	0,3	0,6	0,5	0,6	1,0	0,4	–0,5

Table 4.1.29 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	0,1	0,1	0,8	0,8	0,1	0,1
f_{mh}	0,0	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	–0,7	–0,4	–0,4	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–0,7	–0,4	–0,4	1,0	1,0	0,1	0,3
$f_{v\text{-}stb}$	–0,7	–0,4	–0,4	1,0	1,0	0,3	0,1
f_t	0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}pt}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}stb}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}ctr}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,4	0,4	–0,9	–0,9	–0,5	–0,5
$f_{bilge\text{-}stb}$	0,3	0,5	0,5	–0,2	–0,2	–0,7	0,6
$f_{WL\text{-}stb}$	0,2	1,0	1,0	–0,1	–0,1	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	0,4	0,4	–0,9	–0,9	–0,5	–0,5
$f_{bilge\text{-}pt}$	0,3	0,5	0,5	–0,2	–0,2	0,6	–0,7
$f_{WL\text{-}pt}$	0,2	1,0	1,0	–0,1	–0,1	0,7	–0,7

Table 4.1.30 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,5	0,1	0,1	0,1	0,1	0,9	0,9	–0,3	–0,3
f_{mh}	0,0	0,1	0,0	–1,0	1,0	–0,7	0,7	–0,1	0,1	0,0	0,0
$f_{v\text{-}mid}$	0,3	1,0	–0,3	0,3	0,3	0,1	0,1	0,2	0,2	–0,3	–0,3
$f_{v\text{-}pt}$	0,3	1,0	–0,3	0,5	0,5	–0,1	0,3	0,2	0,2	–0,3	–0,3
$f_{v\text{-}stb}$	0,3	1,0	–0,3	0,1	0,1	0,3	–0,1	0,2	0,2	–0,3	–0,3
f_t	0,0	–0,1	0,0	1,0	–1,0	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-}pt}$	–0,1	–0,2	1,0	–0,1	0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-}stb}$	–0,1	–0,2	1,0	0,1	–0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-}ctr}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{ctr\text{-}stb}$	0,9	–0,6	–0,4	–0,6	–0,6	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}stb}$	0,3	–0,5	–0,2	–1,0	1,0	–0,7	0,7	0,4	0,4	0,5	0,5
$f_{WL\text{-}stb}$	0,5	–0,2	0,1	–0,9	0,9	–0,6	0,6	0,6	0,6	1,0	1,0
$f_{ctr\text{-}pt}$	0,9	–0,6	–0,4	–0,6	–0,6	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}pt}$	0,3	–0,5	–0,2	1,0	–1,0	0,7	–0,7	0,4	0,4	0,5	0,5
$f_{WL\text{-}pt}$	0,5	–0,2	0,1	0,9	–0,9	0,6	–0,6	0,6	0,6	1,0	1,0

Table 4.1.31 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
f_{mh}	0,1	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,1	0,1
$f_{v\text{-}pt}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	–0,1	0,2
$f_{v\text{-}stb}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,2	–0,1
f_t	–0,1	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0
$f_{bilge\text{-}stb}$	–0,7	0,6	0,7	0,7	1,0	0,9	0,8	0,7	–0,7	0,6

$f_{WL\text{-}stb}$	–0,4	0,4	0,6	0,6	0,9	0,8	1,0	0,8	–0,6	0,6
$f_{ctr\text{-}pt}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	0,0	0,0
$f_{bilge\text{-}pt}$	–0,7	0,6	0,7	0,7	0,9	1,0	0,7	0,8	0,6	–0,7
$f_{WL\text{-}pt}$	–0,4	0,4	0,6	0,6	0,8	0,9	0,8	1,0	0,6	–0,6

Table 4.1.32 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,1	0,1	0,1	0,3	0,3	–0,5	–0,5
f_{mh}	0,4	–0,1	0,1	–0,4	0,4	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,3	–0,3	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	1,0	–0,3	–0,3	1,0	1,0	0,1	0,5
$f_{v\text{-}stb}$	1,0	–0,3	–0,3	1,0	1,0	0,5	0,1
f_t	0,0	0,1	–0,1	0,3	–0,3	1,0	1,0
$f_{lng\text{-}mid}$	0,7	0,7	0,7	–0,4	–0,4	–0,2	–0,2
$f_{lng\text{-}pt}$	0,7	0,7	0,7	–0,4	–0,4	–0,1	–0,4
$f_{lng\text{-}stb}$	0,7	0,7	0,7	–0,4	–0,4	–0,4	–0,1
$f_{lng\text{-}ctr}$	0,7	0,7	0,7	–0,4	–0,4	–0,2	–0,2
$f_{ctr\text{-}stb}$	–1,0	0,4	0,4	–0,7	–0,7	0,6	0,6
$f_{bilge\text{-}stb}$	–1,0	0,5	0,5	–0,4	–0,7	0,1	1,0
$f_{WL\text{-}stb}$	–0,9	1,0	1,0	–0,2	–0,3	0,1	0,9
$f_{ctr\text{-}pt}$	–1,0	0,4	0,4	–0,7	–0,7	0,6	0,6
$f_{bilge\text{-}pt}$	–1,0	0,5	0,5	–0,7	–0,4	1,0	0,1
$f_{WL\text{-}pt}$	–0,9	1,0	1,0	–0,3	–0,2	0,9	0,1

Table 4.1.33 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	1,0	–0,4	0,1	0,1	0,1	0,1	–0,6	–0,6	–0,1	–0,1
f_{mh}	0,0	–1,0	0,0	–1,0	1,0	–0,1	–0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,7	1,0	–0,7	–0,5	–0,5	0,3	0,3	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,7	1,0	–0,7	–0,5	–0,5	0,2	0,5	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,7	1,0	–0,7	–0,5	–0,5	0,5	0,2	–0,2	–0,2	–0,1	–0,1
f_t	0,0	–0,2	0,0	0,2	0,2	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,3	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3

$f_{lng\text{-}pt}$	–0,3	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,3	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,3	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}stb}$	0,8	0,9	0,3	–0,2	0,5	–0,7	0,3	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}stb}$	0,9	0,8	0,5	–0,1	0,4	–0,6	0,3	–0,7	–0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,8	0,9	0,3	0,5	–0,2	0,3	–0,7	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}pt}$	0,9	0,8	0,5	0,4	–0,1	0,3	–0,6	–0,7	–0,7	1,0	1,0

Table 4.1.34 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,1	0,1	0,1	0,1	0,1	0,1	–0,2	–0,2	–0,4	–0,4
f_{mh}	–0,2		–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,5	0,5
$f_{v\text{-}mid}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
$f_{v\text{-}pt}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
$f_{v\text{-}stb}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
f_t			0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,5
$f_{lng\text{-}pt}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,6	–0,6
$f_{lng\text{-}stb}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,5
$f_{ctr\text{-}stb}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}stb}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,9	–0,6
$f_{WL\text{-}stb}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,9	–0,4
$f_{ctr\text{-}pt}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}pt}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,6	–0,9
$f_{WL\text{-}pt}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,4	–0,9

Table 4.1.35 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,6	0,2	0,2	–0,5	–0,5	–0,8	–0,8
f_{mh}	0,0	–0,1	0,1	–0,4	0,4	–1,0	1,0
$f_{v\text{-}mid}$	0,3	–0,1	–0,1	1,0	1,0	0,3	0,3

$f_{v\text{-}pt}$	0,3	–0,1	–0,1	1,0	1,0	0,2	0,5
$f_{v\text{-}stb}$	0,3	–0,1	–0,1	1,0	1,0	0,5	0,2
f_t	0,0	0,1	–0,1	0,3	–0,3	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,3	–0,5
$f_{lng\text{-}stb}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–1,0	0,2	0,2	–0,4	–0,4	–0,2	–0,2
$f_{bilge\text{-}stb}$	–1,0	0,2	0,2	–0,4	–0,5	–0,3	0,1
$f_{WL\text{-}stb}$	–1,0	1,0	1,0	–0,2	–0,3	–0,5	0,3
$f_{ctr\text{-}pt}$	–1,0	0,2	0,2	–0,4	–0,4	–0,2	–0,2
$f_{bilge\text{-}pt}$	–1,0	0,2	0,2	–0,5	–0,4	0,1	–0,3
$f_{WL\text{-}pt}$	–1,0	1,0	1,0	–0,3	–0,2	0,3	–0,5

Table 4.1.36 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Campos Basin

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	1,0	0,6	–0,3	–0,3	–0,1	–0,1	–0,6	–0,6	0,1	0,1
f_{mh}	0,0	–1,0	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,6	1,0	–0,8	–0,5	–0,5	0,3	0,3	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,6	1,0	–0,8	–0,5	–0,5	0,2	0,5	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,6	1,0	–0,8	–0,5	–0,5	0,5	0,2	–0,2	–0,2	–0,1	–0,1
f_t	0,0	–0,2	0,0		–0,2	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,4	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}pt}$	–0,4	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,4	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,4	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}stb}$	0,5	0,9	0,3	–0,2	0,5	–0,7	0,3	–0,6	–0,6	0,4	0,4
$f_{WL\text{-}stb}$	0,5	0,8	0,5	–0,1	0,4	–0,6	0,3	–0,7	–0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,5	0,9	0,3	0,5	–0,2	0,3	–0,7	–0,6	–0,6	0,4	0,4
$f_{WL\text{-}pt}$	0,5	0,8	0,5	0,4	–0,1	0,3	–0,6	–0,7	–0,7	1,0	1,0

Table 4.1.37 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–1,0	1,0	1,0	1,0	1,0	–0,3	–0,3	0,2	0,2
f_{mh}	–0,2	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	0,7	–0,7
$f_{v\text{-}mid}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
$f_{v\text{-}pt}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
$f_{v\text{-}stb}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
f_t		0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,6	–0,3
$f_{lng\text{-}stb}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,6
$f_{lng\text{-}ctr}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}stb}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,8	0,8	–0,9	–0,6
$f_{WL\text{-}stb}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,9	–0,4
$f_{ctr\text{-}pt}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}pt}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,8	0,8	–0,6	–0,9
$f_{WL\text{-}pt}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,4	–0,9

Table 4.1.38 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	0,1	0,1	0,2	0,2	0,1	0,1
f_{mh}	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,1	–0,1	–0,1	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	0,1	–0,1	–0,1	1,0	1,0	0,1	0,4
$f_{v\text{-}stb}$	0,1	–0,1	–0,1	1,0	1,0	0,4	0,1
f_t	0,0	0,1	–0,1	0,4	–0,4	1,0	–1,0
$f_{lng\text{-}mid}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}pt}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}stb}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}ctr}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{ctr\text{-}stb}$	–0,1	0,3	0,3	–0,9	–0,9	0,0	0,0
$f_{bilge\text{-}stb}$	–0,7	0,5	0,5	–0,6	–0,5	0,4	–0,7
$f_{WL\text{-}stb}$	–0,6	1,0	1,0	–0,4	–0,2	0,5	–0,7

$f_{ctr\text{-}pt}$	–1,0	0,3	0,3	–0,9	–0,9	0,0	0,0
$f_{bilge\text{-}pt}$	–0,7	0,5	0,5	–0,5	–0,6	–0,7	0,4
$f_{WL\text{-}pt}$	–0,6	1,0	1,0	–0,2	–0,4	–0,7	0,5

Table 4.1.39 Dynamic load cases for central tank region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,2	–0,4	0,1	0,1	0,1	0,1	–1,0	–1,0	–0,1	–0,1
f_{mh}	0,0	–0,1	0,0	–1,0	1,0	–0,5	0,5	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,2	1,0	–0,6	–0,6	–0,6	0,4	0,4	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,2	1,0	–0,6	–0,6	–0,6	0,2	0,6	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,2	1,0	–0,6	–0,6	–0,6	0,6	0,2	–0,2	–0,2	–0,1	–0,1
f_t	0,0	0,5	0,0	0,1	–0,1	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}pt}$	–0,2	–0,5	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,2	–0,5	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	–0,9	0,1	0,4	0,4	–0,4	–0,4	–0,1	–0,1	0,1	0,1
$f_{bilge\text{-}stb}$	0,5	–0,9	0,2	0,5	0,1	0,2	–0,7	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}stb}$	0,7	–0,6	0,5	0,6	0,2	0,3	–0,8	–0,6	–0,6	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,9	0,1	0,4	0,4	–0,4	–0,4	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,5	–0,9	0,2	0,1	0,5	–0,7	0,2	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}pt}$	0,7	–0,6	0,5	0,2	0,6	–0,8	0,3	–0,6	–0,6	1,0	1,0

Table 4.1.40 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,8	0,1	0,1	0,1	0,1	0,1	–0,2	–0,2	–0,1	–0,1
f_{mh}	0,3	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,4	0,4
$f_{v\text{-}mid}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
$f_{v\text{-}pt}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
$f_{v\text{-}stb}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
f_t	–0,4	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,5

$f_{lng\text{-}stb}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,5	–0,5
$f_{bilge\text{-}stb}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,1	–0,8
$f_{WL\text{-}stb}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,1	–0,9
$f_{ctr\text{-}pt}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,5	–0,5
$f_{bilge\text{-}pt}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,8	–0,1
$f_{WL\text{-}pt}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,9	–0,1

Table 4.1.41 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,6	–0,5	–0,5	–0,6	–0,6	0,3	0,3
f_{mh}	0,0	–0,1	0,1	–0,4	0,4	–1,0	1,0
$f_{v\text{-}mid}$	0,4	–0,2	–0,2	1,0	1,0	–0,1	–0,1
$f_{v\text{-}pt}$	0,4	–0,2	–0,2	1,0	1,0	–0,4	–0,3
$f_{v\text{-}stb}$	0,4	–0,2	–0,2	1,0	1,0	–0,3	–0,4
f_t	0,0	0,1	–0,1	0,4	–0,4	1,0	–1,0
$f_{lng\text{-}mid}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,5	0,5
$f_{lng\text{-}pt}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,4	0,6
$f_{lng\text{-}stb}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,6	0,4
$f_{lng\text{-}ctr}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,5	0,5
$f_{ctr\text{-}stb}$	–1,0	0,9	0,9	–0,5	–0,5	0,2	0,2
$f_{bilge\text{-}stb}$	–1,0	0,9	0,9	–0,7	–0,7	0,6	–0,4
$f_{WL\text{-}stb}$	–0,7	1,0	1,0	–0,3	–0,3	0,8	–0,8
$f_{ctr\text{-}pt}$	–1,0	0,9	0,9	–0,5	–0,5	0,2	0,2
$f_{bilge\text{-}pt}$	–1,0	0,9	0,9	–0,7	–0,7	–0,4	0,6
$f_{WL\text{-}pt}$	–0,7	1,0	1,0	–0,3	–0,3	–0,8	0,8

Table 4.1.42 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,2	0,1	–0,6	–0,6	–0,1	–0,1	–0,9	–0,9	0,9	0,9
f_{mh}	0,0	–0,2	0,0	–1,0	1,0	–0,8	0,8	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,3	1,0	0,2	–0,7	–0,7	0,3	0,3	0,1	0,1	–0,2	–0,2

$f_{v\text{-}pt}$	0,3	1,0	0,2	–0,7	–0,7	0,1	0,5	0,1	0,1	–0,2	–0,2
$f_{v\text{-}stb}$	0,3	1,0	0,2	–0,7	–0,7	0,5	0,1	0,1	0,1	–0,2	–0,2
f_t	0,0	0,5	0,0	0,1	–0,1	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,2	–0,3	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}pt}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}stb}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}ctr}$	–0,2	–0,3	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{ctr\text{-}stb}$	0,8	–0,8	–0,1	0,3	0,3	–0,2	–0,2	–1,0	–1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,4	–0,9	–0,1	0,6	0,1	0,4	–0,8	–0,7	–0,7	0,7	0,7
$f_{WL\text{-}stb}$	0,5	–0,5	–0,2	0,7	0,1	0,4	–0,7	–0,7	–0,7	0,9	0,9
$f_{ctr\text{-}pt}$	0,8	–0,8	–0,1	0,3	0,3	–0,2	–0,2	–1,0	–1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,4	–0,9	–0,1	0,1	0,6	–0,8	0,4	–0,7	–0,7	0,7	0,7
$f_{WL\text{-}pt}$	0,5	–0,5	–0,2	0,1	0,7	–0,7	0,4	–0,7	–0,7	0,9	0,9

Table 4.1.43 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,2	–1,0	0,9	0,9	0,9	0,9	–0,7	–0,7	0,1	0,1
f_{mh}	–0,5	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–1,0	1,0
$f_{v\text{-}mid}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
$f_{v\text{-}pt}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
$f_{v\text{-}stb}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
f_t	–0,4	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,3	–0,5
$f_{lng\text{-}stb}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,4	–0,4
$f_{ctr\text{-}stb}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,5	–0,5
$f_{bilge\text{-}stb}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,1	–0,8
$f_{WL\text{-}stb}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,1	–0,9
$f_{ctr\text{-}pt}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,5	–0,5
$f_{bilge\text{-}pt}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,8	–0,1
$f_{WL\text{-}pt}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,9	–0,1

Table 4.1.44 Dynamic load cases for aft end region for deep draught condition for a spread moored VLCC unit Nigeria

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P

f_{mv}	0,8	0,1	0,1	0,1	0,1	0,1	–0,1
f_{mh}	0,1	–0,4	–0,4	0,0	0,0	0,3	–0,3
$f_{v\text{-}mid}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
$f_{v\text{-}pt}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
$f_{v\text{-}stb}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
f_t	–0,1	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}pt}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}stb}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}ctr}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{ctr\text{-}stb}$	1,0	0,3	0,3	0,2	0,2	0,1	–0,1
$f_{bilge\text{-}stb}$	0,9	0,5	0,5	0,1	0,1	–0,3	0,3
$f_{WL\text{-}stb}$	0,7	1,0	1,0	0,1	0,1	–0,3	0,3
$f_{ctr\text{-}pt}$	1,0	0,3	0,3	0,2	0,2	0,1	–0,1
$f_{bilge\text{-}pt}$	0,9	0,5	0,5	0,1	0,1	–0,3	0,3
$f_{WL\text{-}pt}$	0,7	1,0	1,0	0,1	0,1	–0,3	0,3

Table 4.1.45 Dynamic load cases for central tank region for deep draught condition for a spread moored VLCC unit Nigeria

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,7	–0,4	0,5	–0,5	0,2	–0,2	–0,6	–0,6	–0,5	–0,5
f_{mh}	0,0	–0,6	0,5	–1,0	1,0	–0,1	0,1	0,0	0,0	–0,1	–0,1
$f_{v\text{-}mid}$	0,8	1,0	–0,6	0,6	–0,6	0,2	–0,2	0,0	0,0	0,1	0,1
$f_{v\text{-}pt}$	0,8	1,0	–0,6	0,6	–0,6	0,2	–0,2	0,0	0,0	0,1	0,1
$f_{v\text{-}stb}$	0,7	1,0	–0,6	0,6	–0,6	0,3	–0,3	0,0	0,0	0,1	0,1
f_t	0,0	0,1	0,0	0,2	–0,2	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}pt}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}stb}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{ctr\text{-}stb}$	–0,9	–0,2	0,1	–0,3	0,3	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	–0,8	0,4	–0,2	0,3	–0,3	–0,8	0,8	1,0	1,0	1,0	1,0
$f_{WL\text{-}stb}$	–0,7	0,2	–0,1	0,3	–0,3	–0,4	0,4	0,9	0,9	1,0	1,0
$f_{ctr\text{-}pt}$	–0,9	–0,2	0,1	–0,3	0,3	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	–0,8	0,4	–0,2	0,3	–0,3	–0,8	0,8	1,0	1,0	1,0	1,0
$f_{WL\text{-}pt}$	–0,7	0,2	–0,1	0,3	–0,3	–0,4	0,4	0,9	0,9	1,0	1,0

Table 4.1.46 Dynamic load cases for forward end region for deep draught condition for a spread moored VLCC unit, Nigeria

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,5	0,5	–0,4	–0,4	–0,4	–0,4	–0,3	–0,3	–0,1	0,1
f_{mh}	–0,2	0,2	–0,1	–0,1	–0,1	–0,1	0,1	0,1	0,9	–0,9
$f_{v\text{-}mid}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{v\text{-}pt}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	–0,1
$f_{v\text{-}stb}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	–0,1
f_t	0,1	–0,1	0,1	0,1	0,1	0,1	0,3	0,3	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{lng\text{-}pt}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{ctr\text{-}stb}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{bilge\text{-}stb}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,9	0,9	0,5	–0,5
$f_{WL\text{-}stb}$	0,6	–0,6	0,8	0,8	0,8	0,8	1,0	1,0	0,2	–0,2
$f_{ctr\text{-}pt}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{bilge\text{-}pt}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,9	0,9	0,5	–0,5
$f_{WL\text{-}pt}$	0,6	–0,6	0,8	0,8	0,8	0,8	1,0	1,0	0,2	–0,2

Table 4.1.47 Dynamic load cases for aft end region for light draught condition for a spread moored VLCC unit, Nigeria

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	0,9	0,9	0,3	0,3	0,4	–0,4
f_{mh}	–0,2	–0,5	–0,5	0,2	0,2	0,6	–0,6
$f_{v\text{-}mid}$	0,5	0,0	0,0	1,0	1,0	0,5	–0,5
$f_{v\text{-}pt}$	0,5	0,0	0,0	1,0	1,0	0,5	–0,5
$f_{v\text{-}stb}$	0,5	0,0	0,0	1,0	1,0	0,5	–0,5
f_t	–0,1	–0,1	–0,1	0,1	0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}pt}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}stb}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}ctr}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{ctr\text{-}stb}$	1,0	1,0	1,0	0,4	0,4	0,4	–0,4
$f_{bilge\text{-}stb}$	0,7	0,9	0,9	0,3	0,3	–0,7	0,7
$f_{WL\text{-}stb}$	0,6	1,0	1,0	0,1	0,1	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	1,0	1,0	0,4	0,4	0,4	–0,4

$f_{bilge\text{-}pt}$	0,7	0,9	0,9	0,3	0,3	–0,7	0,7
$f_{WL\text{-}pt}$	0,6	1,0	1,0	0,1	0,1	–0,7	0,7

Table 4.1.48 Dynamic load cases for central tank region for light draught condition for a spread moored VLCC unit, Nigeria

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,3	0,5	–0,5	0,4	–0,4	–0,9	–0,9	–0,2	–0,2
f_{mh}	0,0	–0,2	0,4	–1,0	1,0	–0,5	0,5	0,1	0,1	0,3	0,3
$f_{v\text{-}mid}$	0,6	1,0	–0,5	0,5	–0,5	0,5	–0,5	–0,2	–0,2	0,0	0,0
$f_{v\text{-}pt}$	0,4	1,0	–0,3	0,4	–0,4	0,9	–0,9	–0,2	–0,2	0,0	0,0
$f_{v\text{-}stb}$	0,4	1,0	–0,3	0,4	–0,4	0,9	–0,9	–0,2	–0,2	0,0	0,0
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,3	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,4	0,4	–0,1	–0,1
$f_{lng\text{-}pt}$	–0,2	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,3	0,3	–0,1	–0,1
$f_{lng\text{-}stb}$	–0,2	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,3	0,3	–0,1	–0,1
$f_{lng\text{-}ctr}$	–0,3	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,4	0,4	–0,1	–0,1
$f_{ctr\text{-}stb}$	–1,0	0,3	0,3	–0,5	0,5	–0,4	0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}stb}$	–0,7	0,4	0,4	–0,7	0,7	0,6	–0,6	0,8	0,8	0,7	0,7
$f_{WL\text{-}stb}$	–0,5	0,0	0,4	–0,8	0,8	0,4	–0,4	0,6	0,6	1,0	1,0
$f_{ctr\text{-}pt}$	–1,0	0,3	0,3	–0,5	0,5	–0,4	0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}pt}$	–0,7	0,4	0,4	–0,7	0,7	0,6	–0,6	0,8	0,8	0,7	0,7
$f_{WL\text{-}pt}$	–0,5	0,0	0,4	–0,8	0,8	0,4	–0,4	0,6	0,6	1,0	1,0

Table 4.1.49 Dynamic load cases for forward end region for light draught condition for a spread moored VLCC unit, Nigeria

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,6	–0,5	0,9	0,9	0,9	0,9	–0,5	–0,5	0,4	–0,4
f_{mh}	–0,1	0,1	0,1	0,1	0,8	0,8	–1,0	–1,0	0,9	–0,9
$f_{v\text{-}mid}$	1,0	–0,8	0,8	0,8	0,3	0,3	0,0	0,0	0,1	–0,1
$f_{v\text{-}pt}$	1,0	–0,8	0,7	0,7	0,1	0,1	0,4	0,4	–0,2	–0,2
$f_{v\text{-}stb}$	1,0	–0,8	0,7	0,7	0,1	0,1	0,4	0,4	–0,2	–0,2
f_t	0,0	0,0	0,0	0,0	0,9	0,9	–1,0	–1,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	–0,7	–0,7	–0,1	–0,1	–0,1	–0,1	0,1	–0,1
$f_{lng\text{-}pt}$	–1,0	1,0	–0,7	–0,7	–0,2	–0,2	0,0	0,0	0,0	0,0
$f_{lng\text{-}stb}$	–1,0	1,0	–0,7	–0,7	–0,2	–0,2	0,0	0,0	0,0	0,0
$f_{lng\text{-}ctr}$	–1,0	1,0	–0,7	–0,7	–0,1	–0,1	–0,1	–0,1	0,1	–0,1
$f_{ctr\text{-}stb}$	0,8	–0,7	1,0	1,0	0,7	0,7	–0,2	–0,2	0,2	–0,2

$f_{bilge-stb}$	0,6	–0,5	0,7	0,7	1,0	1,0	–1,0	–1,0	0,8	–0,8
f_{WL-stb}	0,4	–0,3	0,6	0,6	–0,3	–0,3	1,0	1,0	–0,7	0,7
f_{ctr-pt}	0,8	–0,7	1,0	1,0	0,7	0,7	–0,2	–0,2	0,2	–0,2
$f_{bilge-pt}$	0,6	–0,5	0,7	0,7	1,0	1,0	–1,0	–1,0	0,8	–0,8
f_{WL-pt}	0,4	–0,3	0,6	0,6	–0,3	–0,3	1,0	1,0	–0,7	0,7

Table 4.1.50 Dynamic load cases for strength assessment (by FEM), unrestricted worldwide transit

Wave direction	Head sea				Beam sea		Oblique sea	
Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–1,0	1,0	0,0	0,0	0,4	0,4
f_{qv}	1,0	–1,0	1,0	–1,0	0,0	0,0	0,0	0,0
f_{mh}	0,0	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
f_v	0,5	–0,5	0,3	–0,3	1,0	1,0	–0,1	–0,1
f_t	0,0	0,0	0,0	0,0	–0,6	0,6	0,0	0,0
f_{lng}	–0,6	0,6	–0,6	0,6	–0,5	–0,5	0,5	0,5
f_{WL-pt}	–0,3	0,3	0,1	–0,1	1,0	0,4	0,6	0,0
$f_{bilge-pt}$	–0,3	0,3	0,1	–0,1	1,0	0,4	0,4	0,0
f_{ctr-pt}	–0,7	0,7	0,3	–0,3	0,9	0,9	0,5	0,5
f_{WL-stb}	–0,3	0,3	0,1	–0,1	0,4	1,0	0,0	0,6
$f_{bilge-stb}$	–0,3	0,3	0,1	–0,1	0,4	1,0	0,0	0,4
$f_{ctr-stb}$	–0,7	0,7	0,3	–0,3	0,9	0,9	0,5	0,5

Table 4.1.51 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, west of Shetland Is.

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,9	0,9	0,4	0,4	0,2	0,2
f_{qv}	1,0	–1,0	1,0	–1,0	–0,2	–0,2	–0,2	–0,2
f_{mh}	0,1	–0,1	0,0	0,0	–0,2	0,2	–1,0	1,0
f_v	–0,6	0,6	–0,2	0,2	1,0	1,0	0,0	0,0
f_t	0,0	0,0	0,0	0,0	0,2	–0,2	0,0	0,0
f_{lng}	0,6	–0,6	0,1	–0,1	–0,1	–0,1	0,6	0,6
f_{WL-pt}	–0,8	0,8	–0,8	0,8	–0,2	–0,7	–0,1	0,3
$f_{bilge-pt}$	–0,5	0,5	–0,5	0,5	–0,5	–1,0	–0,1	0,4
f_{ctr-pt}	–1,0	1,0	–1,0	1,0	–1,0	–1,0	0,2	0,2

f_{WL-stb}	–0,8	0,8	–0,8	0,8	–0,7	–0,2	0,3	–0,1
$f_{bilge-stb}$	–0,5	0,5	–0,5	0,5	–1,0	–0,5	0,4	–0,1
$f_{ctr-stb}$	–1,0	1,0	–1,0	1,0	–1,0	–1,0	0,2	0,2

Table 4.1.52 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, North Sea

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,8	0,8	0,3	0,3	–0,3	–0,3
f_{qv}	0,8	–0,8	1,0	–1,0	–0,2	0,2	0,1	0,1
f_{mh}	0,3	–0,3	0,1	–0,1	–0,1	0,1	–1,0	1,0
f_v	–0,7	0,7	–0,1	0,1	1,0	1,0	–0,3	–0,3
f_t	–0,1	0,1	0,0	0,0	0,3	–0,3	0,1	–0,1
f_{lng}	0,9	–0,9	0,2	–0,2	–0,1	–0,1	0,4	0,4
f_{WL-pt}	–0,8	0,8	–1,0	1,0	–0,2	–0,5	0,1	–0,2
$f_{bilge-pt}$	–0,6	0,6	–0,9	0,9	–0,6	–0,9	0,2	0,3
f_{ctr-pt}	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,1	–0,2
f_{WL-stb}	–0,8	0,8	–1,0	1,0		–0,2	–0,2	
$f_{bilge-stb}$	–0,6	0,6	–0,9	0,9	–0,9	–0,6	–0,3	0,2
$f_{ctr-stb}$	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,2	–0,1

Table 4.1.53 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Brazil

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,8	0,8	0,4	0,4	–0,2	–0,2
f_{qv}	0,9	–0,9	1,0	–1,0	–0,2	–0,2	0,2	0,2
f_{mh}	0,4	–0,4	–0,1	–0,1	–0,2	–0,2	–1,0	1,0
f_v	–0,5	0,5	–0,2	0,2	1,0	1,0	–0,1	–0,1
f_t	–0,1	0,1	0,0	0,0	0,2	–0,2	0,1	–0,1
f_{lng}	1,0	–1,0	0,4	–0,4	–0,1	–0,1	0,4	0,4
f_{WL-pt}	–0,6	0,6	–0,8	0,8	–0,2	–0,5	0,1	–0,2
$f_{bilge-pt}$	–0,3	0,3	–0,4	0,4	–0,5	–0,6	0,1	–0,2
f_{ctr-pt}	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2
f_{WL-stb}	–0,6	–0,6	–0,8	0,8	–0,5	–0,2	–0,2	0,1
$f_{bilge-stb}$	–0,3	0,3	–0,4	0,4	–0,6	–0,5	–0,2	0,1
$f_{ctr-stb}$	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2

Table 4.1.54 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–1,0	1,0	0,8	0,8	0,4	0,4
f_{qv}	1,0	–1,0	1,0	–1,0	–0,6	–0,6	–0,2	–0,2
f_{mh}	0,1	–0,1	–0,1	0,1	–0,1	0,1	–1,0	1,0
f_v	–0,4	0,4	–0,4	0,4	1,0	1,0	0,2	0,2
f_t	–0,1	0,1	–0,1	0,1	0,1	–0,1	0,1	–0,1
f_{lng}	0,3	–0,3	0,1	–0,1	–0,4	–0,4	–0,6	–0,6
f_{WL-pt}	–0,4	0,4	–0,5	0,5	–0,1	–0,2	–0,1	0,3
$f_{bilge-pt}$	–0,2	0,2	–0,2	0,2	–0,5	–0,5	–0,2	0,3
f_{ctr-pt}	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2
f_{WL-stb}	–0,4	0,4	–0,5	0,5		–0,1	0,3	–0,1
$f_{bilge-stb}$	–0,2	0,2	–0,2	0,2	–0,5	–0,5	0,3	–0,2
$f_{ctr-stb}$	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2

Table 4.1.55 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Brazil ampos Basin

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,4	0,4	1,0	1,0	0,3	0,3
f_{qv}	0,7	–0,7	1,0	–1,0	1,0	1,0	–1,0	–1,0
f_{mh}	0,0	0,0	0,0	0,0	–1,0	1,0	–1,0	1,0
f_v	0,7	0,7	–0,5	0,5	1,0	1,0	–0,5	–0,5
f_t	0,0	0,0	0,0	0,0	0,2	–0,2	0,2	–0,2
f_{lng}	0,3	–0,3	0,7	–0,7	–0,4	–0,4	–0,1	–0,1
f_{WL-pt}	–0,8	0,8	–0,5	0,5	0,2	0,8	0,4	–0,1
$f_{bilge-pt}$	–0,8	0,8	–0,3	0,3	0,3	0,9	0,6	–0,3
f_{ctr-pt}	–1,0	1,0	–0,2	0,2	1,0	1,0	0,2	0,2
f_{WL-stb}	–0,8	0,8	–0,5	0,5	0,8	0,2	–0,1	0,4
$f_{bilge-stb}$	–0,8	0,8	–0,3	0,3	0,9	0,3	–0,3	0,6
$f_{ctr-stb}$	–1,0	1,0	–0,2	0,2	1,0	1,0	0,2	0,2

Table 4.1.56 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,5	0,5	0,2	0,2	0,6	0,6
f_{qv}	0,5	–0,5	1,0	–1,0	–0,2	–0,2	1,0	1,0
f_{mh}	0,0	0,0	0,0	0,0	–0,2	–0,2	–1,0	–1,0
f_v	–0,3	0,3	–0,5	0,5	1,0	1,0	–0,6	–0,6
f_t	0,0	0,0	0,0	0,0	0,5	–0,5	0,1	–0,1
f_{lng}	0,2	–0,2	0,6	–0,6	–0,5	–0,5	0,1	0,1
$f_{WL\text{-}pt}$	–0,7	0,7	–0,4	0,4	–0,2	–0,5	0,2	0,6
$f_{bilge\text{-}pt}$	–0,5	0,5	–0,2	0,2	–0,6	–1,0	0,1	0,6
$f_{ctr\text{-}pt}$	–1,0	1,0	–0,3	0,3	–0,9	–0,9	0,4	0,4
$f_{WL\text{-}stb}$	–0,7	0,7	–0,4	0,4	–0,5	–0,2	0,6	0,2
$f_{bilge\text{-}stb}$	–0,5	0,5	–0,2	0,2	–1,0	–0,6	0,6	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	–0,3	0,3	–0,9	–0,9	0,4	0,4

Table 4.1.57 Dynamic load cases for strength assessment by FEM for a spread moored VLCC unit, Nigeria

Max. response	M_{wv}	M_{wv}	Q_{wv}	Q_{wv}	a_v	a_v	$M_{wv\text{-}h}$	$M_{wv\text{-}h}$
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	0,4	–0,4	0,7	0,7	0,5	–0,5
f_{qv}	0,0	0,0	–1,0	1,0	1,0	1,0	0,7	–0,7
f_{mh}	0,0	0,0	–0,4	0,4	–0,6	–0,6	–1,0	1,0
f_v	–0,8	0,8	0,6	–0,6	1,0	1,0	0,6	–0,6
f_t	0,0	0,0	0,0	0,0	0,1	0,1	0,2	–0,2
f_{lng}	0,0	0,0	–1,0	1,0	–1,0	–1,0	–0,6	0,6
$f_{WL\text{-}pt}$	0,7	–0,7	0,2	–0,2	0,2	0,2	0,3	–0,3
$f_{bilge\text{-}pt}$	0,8	–0,8	0,3	–0,3	0,4	0,4	0,3	–0,3
$f_{ctr\text{-}pt}$	0,9	–0,9	–0,1	0,1	–0,2	–0,2	–0,3	0,3
$f_{WL\text{-}stb}$	0,7	–0,7	0,2	–0,2	0,2	0,2	0,3	–0,3
$f_{bilge\text{-}stb}$	0,8	–0,8	0,3	–0,3	0,4	0,4	0,3	–0,3
$f_{ctr\text{-}stb}$	0,9	–0,9	–0,1	0,1	–0,2	–0,2	–0,3	0,3

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1 General

Section 1
General

1.1 Guide to the reader

1.1.1 This Part incorporates risk mitigation measures taken and adapted from the revised *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (*2014 IGC Code - International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk*). However, if alternative measures have been defined for an installation, in accordance with the operating philosophy or safety philosophy of the installation, these alternative measures may be considered.

1.2 Application and implementation

1.2.1 The purpose of this Part is to provide requirements to ensure the safe operation and inspection/maintenance of ship units engaged in the production, storage and offloading of liquefied gases at a fixed location. Ship units engaged solely in the storage and offloading of liquefied gases at a fixed location are also to comply with this Part, as applicable.

Mobile offshore units using natural gas or methane solely as a fuel are not considered within the scope of this part and are to comply with the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2016*

1.2.2 The requirements in this Part are applicable to hull construction in steel.

1.2.3 This Part considers only the design requirements for the production, storage and offloading of liquefied gases of the unit. Ship units are to comply with *Pt 10 SHIP UNITS* and other relevant Parts in addition to the requirements of this Part.

1.2.4 The requirements prescribed in this Part are applicable only to liquefied hydrocarbon gases (liquefied natural gas and liquefied petroleum gas), nitrogen and carbon dioxide. The products for which this Part is applicable are listed in *Pt 11, Ch 19 Summary of Minimum Requirements*. Requirements are not prescribed for products that are considered toxic by the IGC Code. Proposals to produce, store and offload products not listed in *Pt 11, Ch 19 Summary of Minimum Requirements* are to be individually considered and the arrangements are to be acceptable to the Administration.

1.2.5 Integral tanks, that form a structural part of the hull, for the storage of gas condensate are to comply with *Pt 10 SHIP UNITS*, *see Pt 10, Ch 1, 1.1 Application 1.1.12* .

1.2.6 Integral tanks, that form a structural part of the hull, for the bulk storage of liquid chemicals necessary for treatment of the feed gas, e.g. monoethylene glycol (MEG) and amine solvents, are to comply with *Pt 10 SHIP UNITS*, *see Pt 10, Ch 1, 1.1 Application 1.1.13*. The structural design of independent tanks for the bulk storage of liquid chemicals is to comply with the requirements of *Pt 11, Ch 4 Cargo Containment* and *Pt 10, Ch 1, 1.1 Application 1.1.13* (a) and (c).

1.2.7 Flammable liquids having a flashpoint of 60°C (closed-cup test) or less and the flammable products listed in *Pt 11, Ch 19 Summary of Minimum Requirements* shall not be carried in tanks located within the protective zones described in *Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.1*, within the longitudinal extent of the hold spaces for those tanks.

1.2.8 Where a risk assessment or study of similar intent is utilised within this Part, the results shall also include, but not be limited to, the following as evidence of effectiveness:

- Description of methodology and standards applied;
- Potential variation in scenario interpretation or sources of error in the study;
- Validation of the risk assessment process by an independent and suitable third party;
- Quality system under which the risk assessment was developed;
- The source, suitability and validity of data used within the assessment;
- The knowledge base of persons involved within the assessment;
- System of distribution of results to relevant parties;
- Validation of results by an independent and suitable third party.

1.2.9 The risk and consequences of stratification and rollover of liquefied gas in storage tanks are to be considered. Methods to reduce the possibility of stratification are to be considered, e.g.:

- ability to fill the tank from both the top and bottom;
- recirculation of tank inventory through jet nozzles or other mixing devices.

Methods to detect stratification are also to be considered.

1.3 Definitions

1.3.1 Except where expressly provided otherwise, the following definitions apply to this Part. Additional definitions are provided in Chapters throughout this Part:

(a) **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries without cooking appliances and similar spaces.

(b) **'A' class divisions** are divisions as defined in Regulation*Regulation 3 - Definitions .3*of the SOLAS Convention.

(c) **Administration** is defined in *Pt 1, Ch 2, 1 Conditions for classification*. For the purpose of classification, the definition of Administration is to be taken as Lloyd's Register (LR).

(d) **Boiling point** is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.

(e) **Breadth**, *B*, in metres, means the maximum breadth of the ship unit, measured amidships to the moulded line of the frame. For the determination of the scantlings for hull construction, the breadth, *B*, is to be taken as defined in *Pt 4, Ch 1, 5 Definitions*.

(f) **Cargo area** is that part of the ship unit which contains the cargo containment system and cargo pump and compressor rooms and includes the deck areas over the full length and breadth of the part of the ship unit over these spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

(g) **Cargo containment system** is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the hold space.

(h) **Cargo control room** is a space used in the control of cargo handling operations.

(i) **Cargoes** are products, listed in *Pt 11, Ch 19 Summary of Minimum Requirements*, that are carried in bulk by ship units subject to the requirements of this Part.

(j) **Cargo machinery spaces** are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine room.

(k) **Cargo pumps** are pumps used for the transfer of liquid cargo, including main pumps, booster pumps, spray pumps, etc.

(l) **Cargo service spaces** are spaces within the cargo area used for workshops, lockers and storerooms that are of more than 2 m^2 in area.

(m) **Cargo tank**is the liquid-tight shell designed to be the primary container of the cargo and includes all such containment systems whether or not they are associated with the insulation or/and the secondary barriers.

(n) **Closed loop sampling** is a cargo sampling system that minimises the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling.

(o) **Cofferdam** is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

(p) **Control stations** are those spaces in which the ship unit's radio or emergency source of power is located, or where the fire recording or fire control equipment is centralised. This does not include special fire control equipment, which can be most practically located in the cargo area.

(q) **Flammability limits** are the conditions defining the state of fuel oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

(r) **Flammable products** are those identified by an 'F' in column 'f' in the Table in *Pt 11, Ch 19 Summary of Minimum Requirements*.

(s) **FSS Code** is the Fire Safety Systems Code meaning the *International Code for Fire Safety Systems* as adopted by the Maritime Safety Committee of the Organisation by Resolution MSC.98(73), as amended.

(t) **Gas carrier** is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in *Chapter 19 Summary of Minimum Requirements*.

(u) **Gas Combustion Unit (GCU)** is a means of disposing of excess cargo vapour by thermal oxidation, *see also* (ax).

(v) **Gas consumer** is any unit within the vessel using cargo vapour as a fuel.

(w) **Hazardous area** is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment. *See Pt 7, Ch 2, 1 Hazardous areas – General*, and *Pt 7, Ch 2, 2 Classification of hazardous areas* and IEC 60092-502 *Electrical installations in ships - Part 502: Tankers – Special features* for the complete definition of hazardous areas including Classification of Hazardous Areas. When a gas atmosphere is present the following hazards may also be present: toxicity, asphyxiation, corrosiveness, reactivity and low temperature; these hazards shall also be taken into account and additional precautions for the ventilation of spaces and protection of the crew will need to be considered.

(x) **Hold space** is the space enclosed by the structure of the ship unit in which a cargo containment system is situated.

(y) **IBC Code** means the *International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk* adopted by the Maritime Safety Committee of the Organisation by Resolution MSC.4(48), as amended.

(z) **Independent** means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.

(aa) **Insulation space** is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.

(ab) **Interbarrier space** is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material.

(ac) **Length**, *L*, in metres, is the length as defined in the *International Convention on Load Lines.* For the determination of the scantlings for hull construction, the Rule length, *L*, is to be taken as defined in *Pt 4, Ch 1, 5 Definitions*.

(ad) **Machinery spaces** are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces and the trunks to such spaces.

(ae) **Machinery spaces of category A** are those spaces, and trunks to those spaces, which contain:

- (i) internal combustion machinery used for main propulsion for self-propelled units; or
- (ii) internal combustion machinery used for purposes where such machinery has in the aggregate a total power output of not less than 375 kW; or
- (iii) any oil-fired boiler or fuel oil unit or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

(af) **MARPOL** means the *International Convention for the Prevention of Pollution from Ships*, 1973, as modified by the Protocol of 1978 relating thereto, as amended.

(ag) **MARVS** is the maximum allowable relief valve setting of a cargo tank (gauge pressure).

(ah) **Non-hazardous area** is an area other than a hazardous area.

(ai) **Fuel oil unit** is the equipment used for the preparation of fuel oil for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar gauge.

(aj) **Organisation** is the International Maritime Organization (IMO).

(ak) **Permeability** of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

(al) **Primary barrier** is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.

(am) **Products** is the collective term used to cover the list of gases indicated in *Pt 11, Ch 19 Summary of Minimum Requirements* of this Part.

(an) **Public spaces** are those portions of the accommodation that are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

(ao) **Recognised Organisation** is an Organisation authorised by an Administration in accordance with IMO Resolution A.739(18) *Guidelines for the Authorisation of Organisations acting on Behalf of the Administration*, to act on their behalf to survey, certificate and determine tonnages as required by SOLAS, MARPOL and the Load Line Conventions.

(ap) **Recognised standards** are applicable international or national Standards acceptable to LR.

(aq) **Relative density** is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

(ar) **Secondary barrier** is the liquid-resisting outer element of a cargo containment system, designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the structure of the ship unit to an unsafe level. Types of secondary barrier are more fully defined in *Pt 11, Ch 4 Cargo Containment*.

(as) **Separate systems** are those cargo piping and vent systems that are not permanently connected to each other.

(at) **Service spaces** are those used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

(au) **SOLAS Convention** means the *International Convention for the Safety of Life at Sea*, 1974, as amended.

(av) **Tank cover** is the protective structure intended either to protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

(aw) **Tank dome** is the upward extension of a portion of a cargo tank. In the case of below deck cargo containment systems, the tank dome protrudes through the weather deck or through a tank cover.

(ax) **Thermal oxidation method** means a system where the boil-off vapours are utilised as fuel for shipboard use or as a waste heat system, subject to the provisions of *Pt 11, Ch 16 Use of Cargo as Fuel* or a system not using the gas as fuel complying with this Part.

(ay) **Turret compartments** are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.

(az) **Vapour pressure** is the equilibrium pressure of the saturated vapour above the liquid, expressed in bars absolute at a specified temperature.

(ba) **Design vapour pressure** 'P_0' is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

(bb) **Void space** is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, fuel oil tank, cargo pumps or compressor room, or any space in normal use by personnel.

1.4 Alternative arrangements

1.4.1 Alternative arrangements or fittings which are considered to be equivalent to those specified in these Rules will be accepted. Arrangements or systems incorporating features not provided for in these Rules will be specially considered.

1.5 Survey requirements

1.5.1 Ship units engaged in the production, storage and offloading of liquefied gases are to comply with the survey requirements given in *Pt 1, Ch 3 Periodical Survey Regulations* and other relevant Parts of the Rules.

1.6 Class notations and descriptive notes

1.6.1 The class notations and descriptive notes applicable to units classed in accordance with these Rules are to be in accordance with *Pt 1, Ch 2 Classification Regulations* and *Pt 3, Ch 3, 1 General*, to which reference should be made.

1.6.2 Where the requirements of this Part are complied with, additional class notations in respect of the following items will be assigned as appropriate:

- Type of tanks.
- Name(s) of gas(es).
- Maximum vapour pressure.
- Minimum and (where necessary) maximum cargo temperature.
- Design ambient temperatures.

1.6.3 The class notation ✠ **Lloyd's RMC(LG)** is mandatory when reliquefaction and/or refrigeration equipment is fitted. The equipment is to be constructed, installed and tested in accordance with the requirements of *Pt 11, Ch 7 Cargo Pressure/ Temperature Control* and elsewhere in these Rules. The minimum temperature for which the installation is suitable will be that given in the main notation unless otherwise qualified.

SDA, **FDA** and **CM** notations are already defined within *Pt 1 REGULATIONS* and *Pt 10 SHIP UNITS*.

1.7 Information and plans

1.7.1 In addition to the plans required by the relevant Parts of these Rules, the following information and plans are to be submitted, where applicable:

- Full particulars of the intended cargo, or cargoes, including maximum vapour pressures, minimum and (where necessary) maximum liquid temperature and other relevant design conditions.
- General arrangement showing location of cargo tanks and the relative location of fuel oil, water ballast and other tanks.
- Openings in main deck.

- Location of void spaces and dangerous zones: openings and access arrangements.
- Details of hull structure in way of cargo tanks, including support arrangements for tanks and associated pipes and fittings, deck sealing arrangements, etc.
- Distribution of quality and grade of steel, supported by calculations of the determined hull steel temperature. The steel grade and temperature in regions where cold spots are likely to occur (e.g. pump supports and where pipes pass through the deck) are also to be indicated.
- Scantlings, materials, and arrangements of the cargo containment system, including primary and (where fitted) secondary barriers, keying and support arrangements, and attachments of fittings, piping, etc.
- Ladders, suction supports and towers inside cargo tanks (arrangements, materials and loadings).
- Tank dome plans.
- End coamings around dome.
- Particulars of filling, discharging, venting, relieving and inerting arrangements.
- Details of test procedures.
- Temperature control arrangements.
- Such information and data as may be required to enable analysis of the hull and containment system structure to be carried out by direct calculation methods.
- Details of personnel protection equipment to be included on the safety plan as applicable to the ship unit.
- Assumptions and details of direct calculations procedures used in the structural analysis of the hull.
- Where horizontal and vertical girders are used to support the bulkhead, the bulkhead scantlings may be determined using direct calculation procedures. The assumptions made and the calculations are to be submitted.

Additional requirements for information and plans may be found in the appropriate Chapters of this Part.

1.7.2 The following plans and particulars for Type C independent tanks are to be submitted for approval before construction is commenced:

- Nature of cargoes, together with maximum vapour pressures and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.
- Particulars of materials proposed for the construction of the vessels.
- General arrangement plan showing location of pressure vessels in the ship unit.
- Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.
- Plans of seating, securing arrangements and deck sealing arrangements.
- Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.
- Details of the arrangements proposed to ensure that the tank or cargo temperature cannot be lowered below the minimum cargo design temperature as defined in *Pt 11, Ch 4, 1.1 Definitions 1.1.3*.
- Plans showing filling, discharging, venting and inerting pipe arrangements, together with particulars of the intended cargo, maximum vapour pressure and minimum liquid temperature.
- Details of calculations and/or model tests are required for the assessment of the tank boundaries with partial filling of tanks.
- Allowable stresses of any materials not covered by *Pt 11, Ch 6 Materials of Construction and Quality Control* required by *Pt 11, Ch 4, 4.3 Design conditions 4.3.2* (e).
- Details verifying compliance with the periodical examination of the secondary barrier required by *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2* (d) if applicable.
- Details of the heating system of the hull structure required by *Pt 11, Ch 4, 5.1 Materials 5.1.2* (e) if fitted.
- Specification and plans of the containment system are to be submitted for approval. Plans are to include:
  - Details of insulation material and, if used, any adhesive, sealers, coatings or similar products.
  - Details of insulation arrangement.
  - Internal bearers or steelwork.
  - Tank supports, chocks, etc.
  - Hatch trunks.
  - Attachment and support of insulation and linings.
  - Data and information to enable a heat leakage calculation to be carried out to assess the capacity of the arrangements provided to deal with boil-off, including:
    - Thermal conductivity of insulation between upper ambient and design temperatures.

- The proposed procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials.
- Calculations and/or analysis of strength of insulation where it is subjected to high mechanical or thermal loads.
- Fatigue and crack propagation properties for insulation in membrane systems are also to be submitted.
- Specifications of the containment system items are to include both those applicable to initial approval of the material, and those applicable to subsequent delivery of batches of material.

Additional requirements for information and plans may be found in the appropriate Chapters of this Part.

1.7.3 The following plans and particulars for Membrane tanks are to be submitted for approval before construction is commenced:

- Recovery Duration (as specified in *Pt 11, Ch 4, 1.1 Definitions 1.1.9*), nature of cargoes, together with maximum vapour pressures and minimum liquid temperature for which the membrane tanks are to be approved.
- Particulars of materials proposed for the construction of the tanks.
- General arrangement plan showing location of membrane tanks in the ship unit and location of relieving devices per tank.
- Plans of membrane tanks showing general construction arrangements and installation methodology.
- Plans of membrane tanks showing insulation panels distribution, levelling and fastening arrangements.
- Plans of membrane tanks showing openings, dimensions, and details of welded joints.
- Details of the arrangements proposed to ensure that the tank or cargo temperature cannot be lowered below the minimum cargo design temperature as defined in *Pt 11, Ch 4, 1.1 Definitions 1.1.3*.
- Plans showing filling, discharging, venting, inerting and draining pipe arrangements, together with particulars of the intended cargo, maximum vapour pressure and minimum liquid temperature.
- Details of calculations and/or model tests, when partial filling of tanks are considered, for the assessment of the containment system integrity.
- Allowable stresses of any materials not covered by *Pt 11, Ch 6 Materials of Construction and Quality Control* required by *Pt 11, Ch 4, 5.1 Materials 5.1.2* (e) .
- Details verifying compliance with the periodical examination or NDT of the secondary barrier required for approval by *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2* (d) if applicable.
- Details of the heating system of the hull structure required by *Pt 11, Ch 4, 5.1 Materials 5.1.2* (f) if fitted.
- Specification and plans for all the containment system components are to be submitted for approval. These plans and specifications are to include:
    - Details of insulation material and, if used, any adhesive, sealers, fillers, coatings or similar products. Properties documented to include:
        - density,
        - elastic modulus and Poisson's ratio,
        - porosity,
        - thixotropic nature,
        - thermal conductivity,
        - thermal expansion/contraction,
        - and any thermal variation of material properties required by the system.
    - Details of insulation arrangement, including installation, welding, gluing, joining procedures and other mechanical means not already covered.
    - Inner hull anchoring flat bars, including definition of surface and levelling quality required.
    - Repair procedures defining imperfection, defects, their allowable limits and subsequent repair processes.
    - Document showing clear system for identification and traceability of parts and components in order to easily act on failure trends.
    - Attachment and support of insulation and linings including bearing limitations in terms of movement, discontinuous connections, angles, steps and spaces.
    - Data and information to enable a heat leakage calculation to be carried out to assess the capacity of the arrangements provided to deal with boil-off, including:
        - Thermal conductivity of insulation between upper ambient and design temperatures.
    - Details of the means of on-site inspection and repair procedures and details of any loads which will be imparted upon the membranes as a result of the on-site inspection and repair procedures. These details need to include:

        - The method to be used.
        - Any loads which will be imparted upon the membranes.
        - The acceptance criteria.
        - The weather conditions for which it will be permitted to undertake inspection and repair operations.
        - The form of record to be made.

        Entry into tank space for inspection purposes should be avoided where possible.

        The testing and inspection should be commensurate with assumptions made in the design of the containment system, *see Pt 11, Ch 4, 4.3 Design conditions 4.3.3*.
    - Details of on-site inspection to be carried out following an exceptional severe event (of similar magnitude of a 10 000 years return period event as per *Pt 11, Ch 4, 2.1 Functional requirements 2.1.7*).
    - Details of proposal for tank preservation in case the intervening period between the cargo tank completion and the first cool down is expected to be significant.
- The proposed procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials.
- Testing results and/or calculations and/or analysis of strength of insulation demonstrating capability to withstand high mechanical and thermal loads.
- Site specific calculations and analyses to include:
    - Sloshing and liquid motion analyses justifying the proposed filling level ranges.
    - Fatigue and crack propagation and tearing properties of insulation system components.
    - Specifications of the containment system items are to include both those applicable to initial approval of the material, and those applicable to subsequent delivery of batches of material.

Additional requirements for information and plans may be found in the appropriate Chapters of this Part.

Section 1 Ship Survival Capability And Location Of Cargo Tanks

1.1 General

1.1.1 The requirements of this Chapter, except for requirement *Pt 11, Ch 2, 1.1 General 1.1.3*on ship unit type description, are not classification requirements. However, in cases where LR is requested to do so by an Owner, Operator or Duty Holder, the requirements of this Chapter will be applied, together with any amendments or interpretations adopted by the appropriate National Authority.

Reference should be made to the *Guidelines for Uniform Application of the Survival Requirements of the Bulk Chemical Code and the Gas Carrier Code.*

1.1.2 Ship units shall survive the hydrostatic effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship unit and the environment, the cargo tanks shall be protected from penetration in the case of minor damage to the ship unit resulting, for example, from contact with a shuttle tanker, offshore support vessel or tug, by locating them at specified minimum distances inboard from the shell plating of the ship unit. Both the damage to be assumed and the proximity of the tanks to the shell of the ship unit should be dependent upon the degree of hazard presented by the product to be carried. In addition, the proximity of the cargo tanks to the shell of the ship unit shall be dependent upon the volume of the cargo tank.

1.1.3 Ship units subject to this Part shall be designed to **Type 2G** standard. Type 2G is defined as a ship unit intended for the storage of liquefied hydrocarbon gases as indicated in *Pt 11, Ch 19 Summary of Minimum Requirements*, that require significant preventive measures to preclude their escape.

1.1.4 For the purpose of this Part, the position of the moulded line for different containment systems is shown in *Figure 2.1.1 Independent prismatic tank, protective distance* to *Figure 2.1.5 Pressure type tank, protective distance*

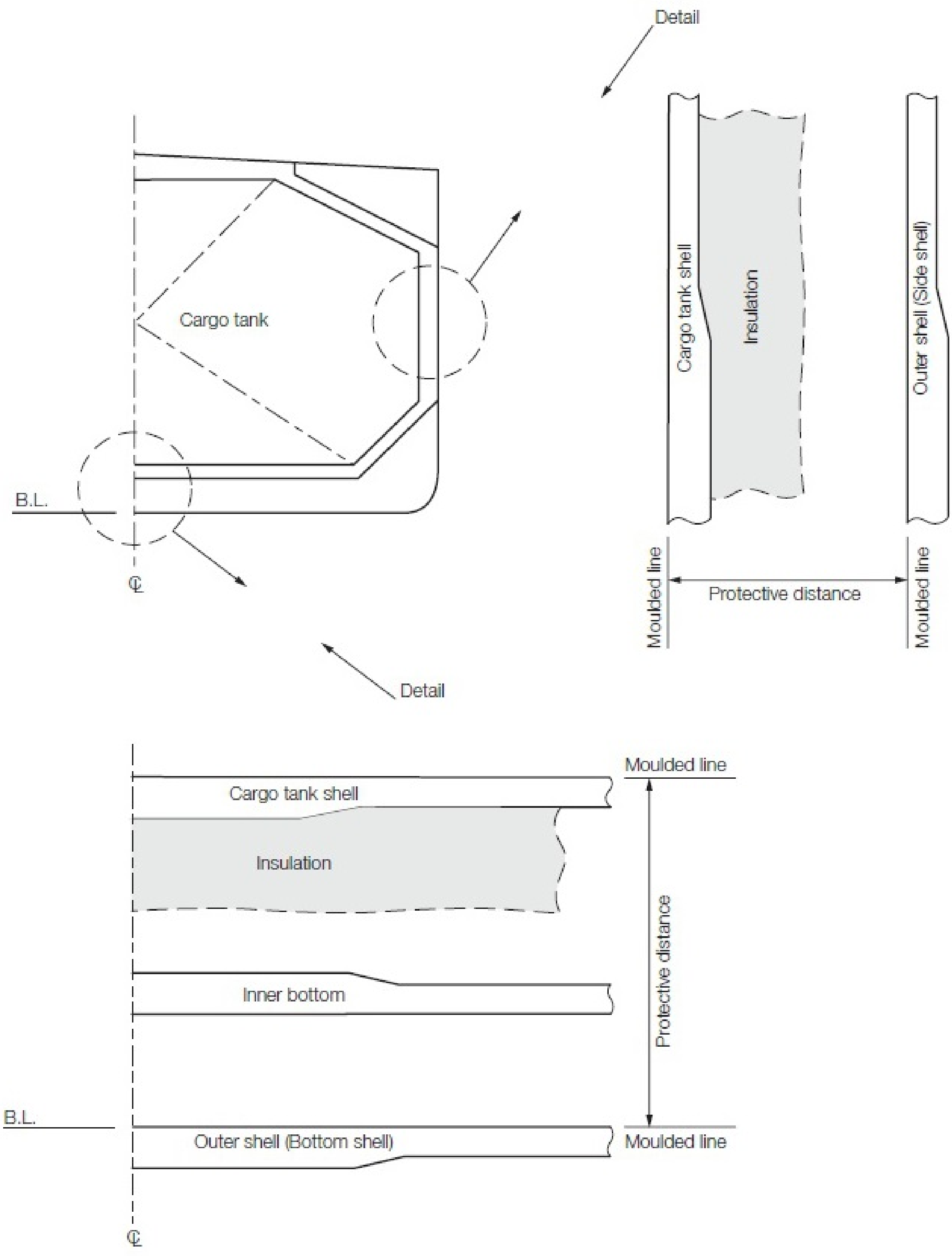


Figure 2.1.1 Independent prismatic tank, protective distance

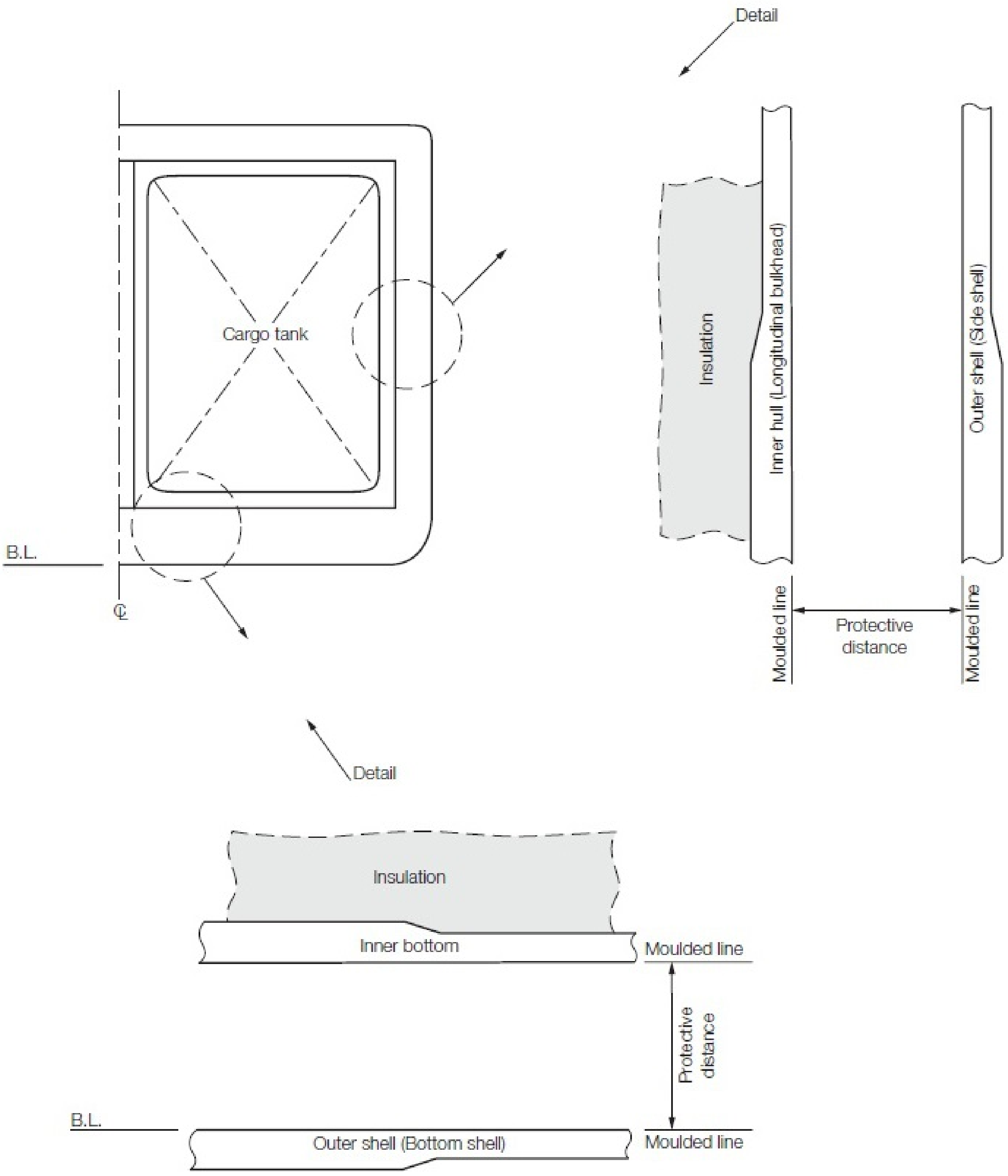


Figure 2.1.2 Semi-membrane tank, protective distance

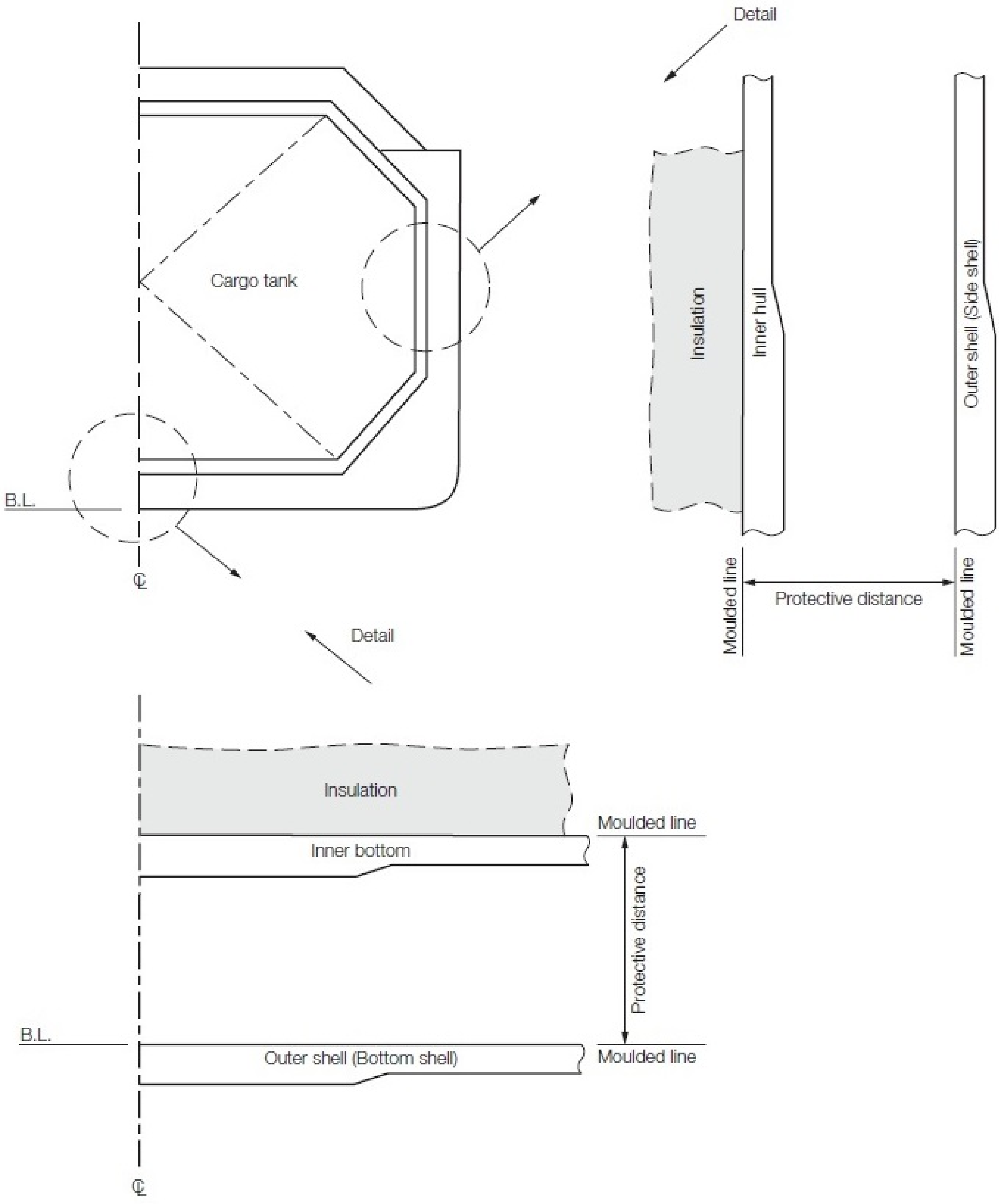


Figure 2.1.3 Membrane tank, protective distance

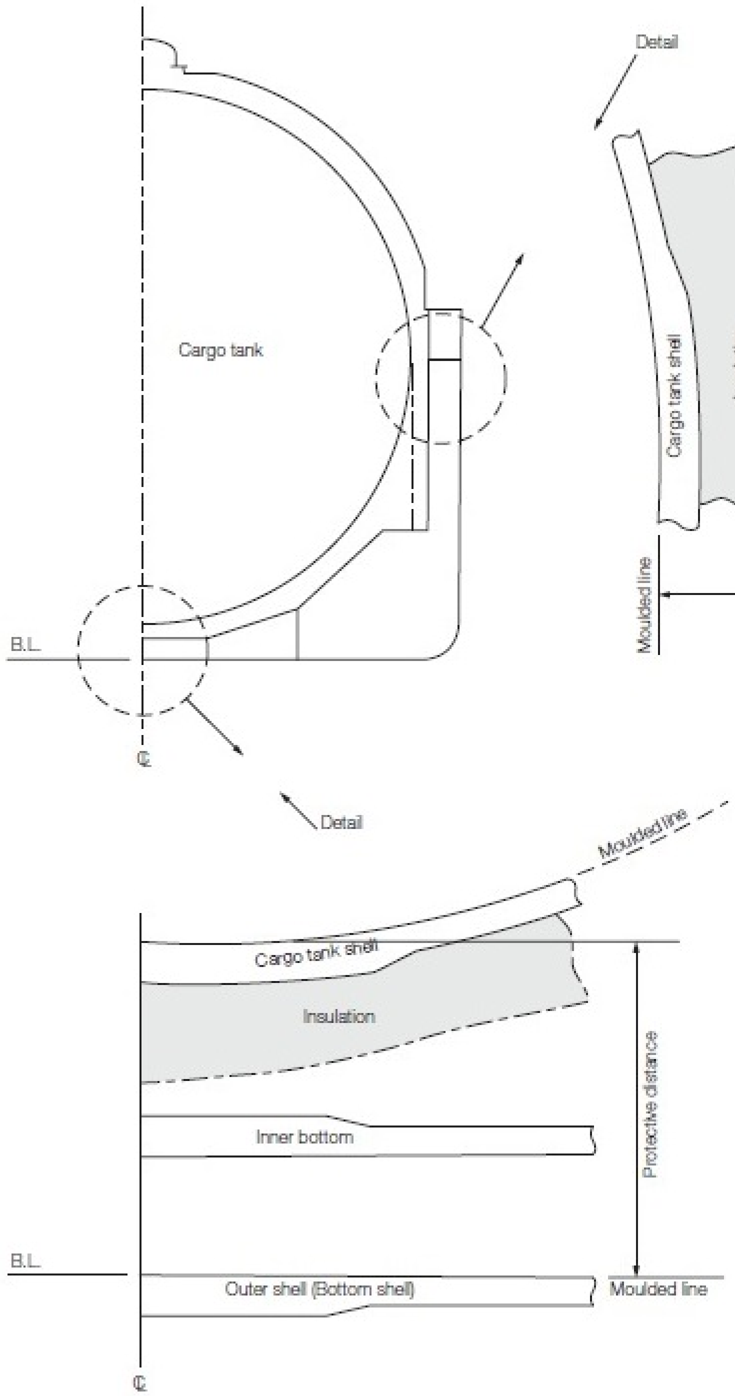


Figure 2.1.4 Spherical tank, protective distance

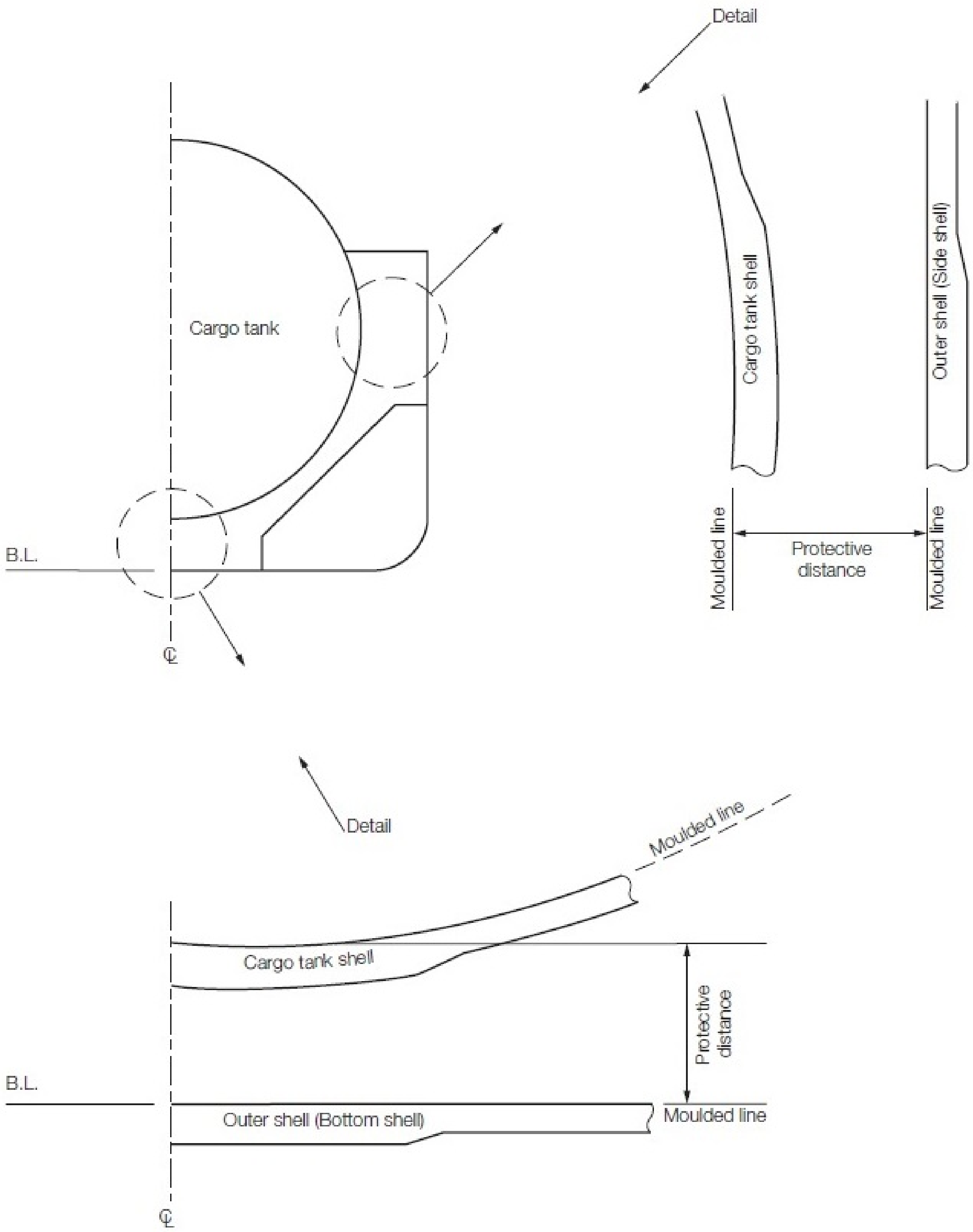


Figure 2.1.5 Pressure type tank, protective distance

1.2 Freeboard and stability

1.2.1 Ship units subject to this Part may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by these Rules.

1.2.2 The stability of the ship unit, in all sea-going conditions including inspection/maintenance, ballasting and during loading and unloading cargo, shall comply with the requirements of the *International Code on Intact Stability*.

1.2.3 When calculating the effect of free surfaces of consumable liquids for loading conditions, it shall be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface. The tank or combination of tanks to be taken into account shall be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments shall be calculated by a method according to the *International Code on Intact Stability*

1.2.4 Solid ballast should not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, its disposition shall be governed by the need to enable access for inspection and to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

1.2.5 The Operator of the ship unit shall be supplied with a loading and stability information booklet. This booklet shall contain details of typical service and inspection/maintenance conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the survival capabilities of the ship unit.

In addition, the booklet shall contain sufficient information to enable the Operator to load and operate the ship unit in a safe and seaworthy manner. *See also Pt 1, Ch 2 Classification Regulations List of abbreviations* and *Pt 10, Ch 3, 1.2 Loading guidance*.

In addition, the Operator is to be given an approved stability instrument to assess the intact stability and the damage stability condition according to the standard damage cases and the actual damage condition of the ship unit. The stability instrument input data and output results have to be approved by the Administration.

1.2.6 Damage survival capability shall be investigated on the basis of loading information submitted to the Administration for all anticipated conditions of loading and variations in draught and trim. This shall include ballast and, where applicable, cargo heel.

1.3 Damage assumptions

1.3.1 The assumed maximum extent of damage shall be as shown in *Table 2.1.1 Assumed maximum extent of damage*.

Table 2.1.1 Assumed maximum extent of damage

Location of damage	Assumed maximum extent of damage	
1. Side damage	To any part of the ship unit	
1.1 Longitudinal extent	$1/3L^{2/3}$ or 14,5 m, whichever is less	
1.2 Transverse extent measured inboard from the moulded line of the outer shell at right angles to the centreline at the level of the summer load line	*B*/5 or 11,5 m, whichever is less	
1.3 Vertical extent from the moulded line of the outer shell at right angles to the centreline at the level of the summer load line	Upwards, without limit	
2. Bottom damage	For 0,3*L* from the forward perpendicular of the ship unit	To any other part of the ship unit
2.1 Longitudinal extent	$1/3L^{2/3}$ or 14,5 m, whichever is less	$1/3L^{2/3}$ or 14,5 m, whichever is less
2.2 Transverse extent	*B*/6 or 10 m, whichever is less	*B*/6 or 5 m, whichever is less
2.3 Vertical extent	*B*/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline, *see Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.3*	*B*/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline, *see Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.3*

1.3.2 **Other damage**

(a) If any damage of a lesser extent than the maximum damage specified in *Table 2.1.1 Assumed maximum extent of damage* would result in a more severe condition, such damage should be assumed.

(b) Local damage anywhere in the cargo area extending inboard distance '*d*' as defined in *Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.1*, measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged, *see Pt 11, Ch 2, 1.6 Standard of damage*. If a damage of a lesser extent than '*d*' would result in a more severe condition, such damage shall be assumed.

1.4 Location of cargo tanks

1.4.1 Cargo tanks shall be located at the following distances inboard:

Type 2G ship unit: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in *Pt 11, Ch 2, 1.3 Damage assumptions* in *Table 2.1.1 Assumed maximum extent of damage* and nowhere less than '*d*' (*see Figure 2.1.6 Cargo tank location requirements, centreline profile, Type 2G ship units* and *Figure 2.1.7 Cargo tank location requirements, transverse sections, Type 2G ship units*), where '*d*' is as follows:

(a) for V_c below or equal to 1000 m^3, d = 0,80 m

(b) for 1000 m^3 < V_c < 5000 m^3,

$d = 0{,}75 + V_c \times 0{,}20/4000$

(c) for 5000 m^3 ≤ V_c < 30 000 m^3,

$d = 0{,}8 + V_c/25\,000$

(d) for V_c ≥ 30 000 m^3, d = 2 m,

where

V_c corresponds to 100 per cent of the gross design volume of the individual cargo tank at 20°C, including domes and appendages. For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s).

NOTE

'*d*' is measured at any cross-section at a right angle from the moulded line of outer shell.

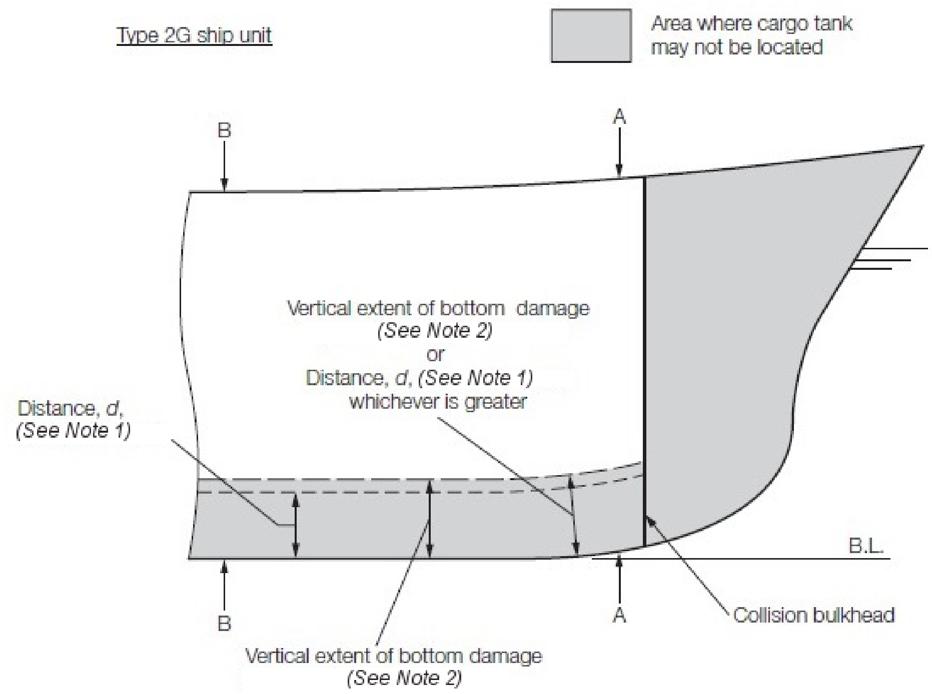


Figure 2.1.6 Cargo tank location requirements, centreline profile, Type 2G ship units

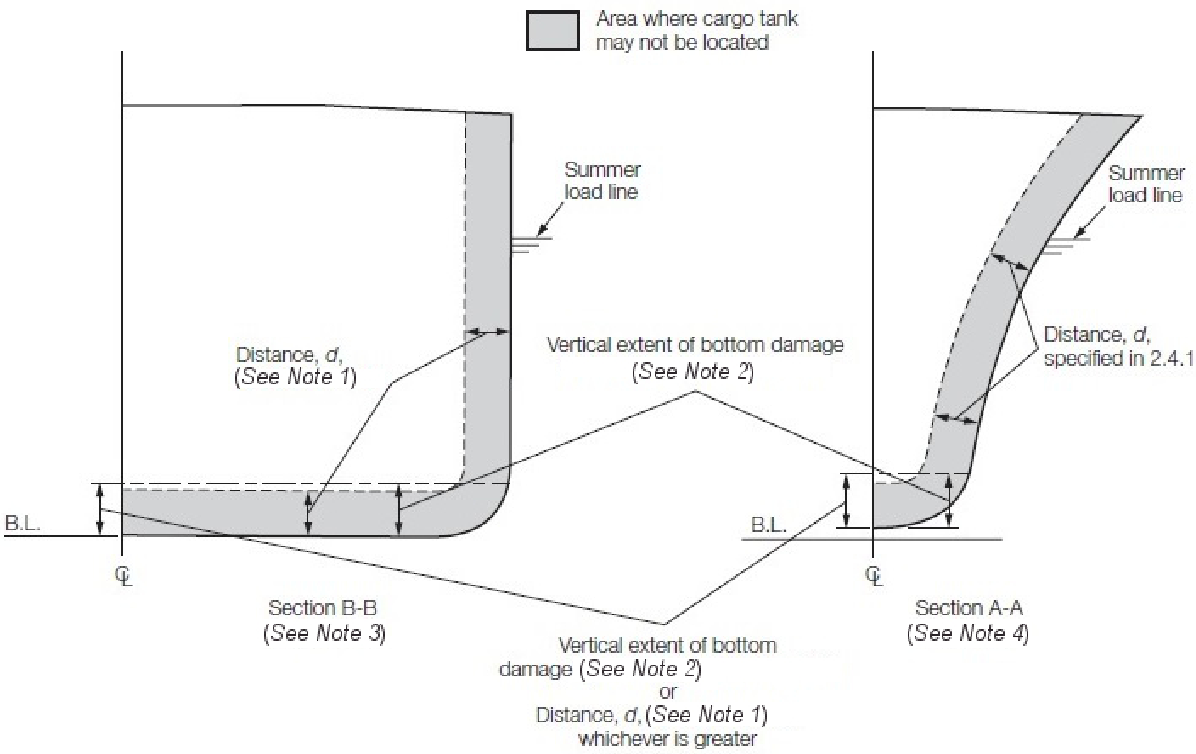


Figure 2.1.7 Cargo tank location requirements, transverse sections, Type 2G ship units

1.4.2 For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semi membrane tanks are used, otherwise to the side of the cargo tanks. The distances indicated in *Pt 11, Ch 2, 1.3 Damage assumptions* and *Pt 11, Ch 2, 1.4 Location of cargo tanks* shall be applied as in *Figure 2.1.1 Independent prismatic tank, protective distance* to *Pt 11, Ch 2, 1.1 General 1.1.4*. These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.

1.4.3 Suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in *Table 2.1.1 Assumed maximum extent of damage* provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25 per cent of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage shall not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored when determining the compartments affected by damage.

1.4.4 Cargo tanks shall not be located forward of the collision bulkhead.

1.4.5 When more than one independent tank is fitted in a space, sufficient clearance is to be left between the tanks for inspection or repairs.

1.5 Flood assumptions

1.5.1 The requirements of *Pt 11, Ch 2, 1.7 Survival requirements* shall be confirmed by calculations that take into consideration the design characteristics of the ship unit, the arrangements, configuration and contents of the damaged compartments, the distribution, relative densities and the free surface effects of liquids and the draught and trim for all conditions of loading.

1.5.2 The permeability of spaces assumed to be damaged shall be as given in *Table 2.1.2 Permeability of spaces assumed to be*

Table 2.1.2 Permeability of spaces assumed to be

Space	Permeability
Stores	0,6
Accommodation	0,95
Machinery	0,85
Voids	0,95
Hold spaces	0,95 *see* Note 1
Consumable liquids	0 to 0,95 *see* Note 2
Other liquids	0 to 0,95 *see* Note 2

Note 1. Other values of permeability can be considered based on detailed calculations; refer to MSC/Circ.651 *Interpretations of part B-1 of SOLAS Chapter II-1.*

Note 2. The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.

1.5.3 Wherever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by saltwater up to the level of the final plane of equilibrium.

1.5.4 The ship unit shall be designed to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

1.5.5 Equalisation arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, shall not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of Survival requirements *Pt 11, Ch 2, 1.7 Survival requirements 1.7.2* and sufficient residual stability shall be maintained during all stages where equalisation is used. Spaces linked by ducts of large cross-sectional area may be considered to be common.

1.5.6 If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in *Pt 11, Ch 2, 1.3 Damage assumptions*, arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

1.5.7 The buoyancy of any superstructure directly above the side damage shall be disregarded. However, the unflooded parts of superstructures beyond the extent of damage may be taken into consideration provided that:

(a) they are separated from the damaged space by watertight divisions and the requirements of *Pt 11, Ch 2, 1.7 Survival requirements 1.7.2* (a) in respect of these intact spaces are complied with; and

(b) openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in *Pt 11, Ch 2, 1.7 Survival requirements 1.7.3* (a). However, the immersion of any other openings capable of being closed weathertight may be permitted.

1.6 Standard of damage

1.6.1 Type 2G ship units shall be capable of surviving the damage indicated in *Pt 11, Ch 2, 1.3 Damage assumptions* anywhere in its length with the flooding assumptions in *Pt 11, Ch 2, 1.5 Flood assumptions*.

1.7 Survival requirements

1.7.1 Ship units shall be capable of surviving the assumed damage specified in *Pt 11, Ch 2, 1.3 Damage assumptions*, to the standard provided in *Pt 11, Ch 2, 1.6 Standard of damage*, in a condition of stable equilibrium and shall satisfy the following criteria.

1.7.2 In any stage of flooding:

(a) the waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings shall include air pipes and openings that are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers that maintain the high integrity of the deck, remotely operated watertight sliding doors and sidescuttles of the non opening type;

(b) the maximum angle of heel due to unsymmetrical flooding shall not exceed 25°, except that this angle may be increased to 30° if no deck immersion occurs; and

(c) the residual stability during intermediate stages of flooding shall not be significantly less than that required by *Pt 11, Ch 2, 1.7 Survival requirements 1.7.3* (a).

1.7.3 At final equilibrium after flooding:

(a) the righting lever curve shall have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0,1 m within the 20° range; the area under the curve within this range shall not be less than 0,0175 m radians. The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs). Unprotected openings shall not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in *Pt 11, Ch 2, 1.7 Survival requirements 1.7.2* (a) and other openings capable of being closed weathertight may be permitted; and

(b) the emergency source of power shall be capable of operating.

Section
1 **Ship Arrangements**

■ *Section 1*
Ship Arrangements

1.1 Segregation of the cargo area and cargo tank holds

1.1.1 In addition to the requirements outlined in this Section, the requirements of *Pt 3, Ch 2 Drilling Units* are to be complied with.

1.1.2 Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A. Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on SOLAS, Regulation 17, after further consideration of involved risks, including that of cargo release and the means of mitigation.

1.1.3 Where cargo is carried in a cargo containment system not requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in *Pt 11, Ch 3, 1.1 Segregation of the cargo area and cargo tank holds 1.1.2* or spaces either below or outboard of the hold spaces may be effected by cofferdams, fuel oil tanks or a single gastight bulkhead of all-welded construction forming an A-60 class division. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.4 Where cargo is carried in a cargo containment system requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in *Pt 11, Ch 3, 1.1 Segregation of the cargo area and cargo tank holds 1.1.2*, or spaces either below or outboard of the hold spaces that contain a source of ignition or fire hazard, shall be effected by cofferdams or fuel oil tanks. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.5 Segregation of turret compartments from spaces referred to in *Pt 11, Ch 3, 1.1 Segregation of the cargo area and cargo tank holds 1.1.2*, or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.6 In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis, *see Pt 11, Ch 1 General* and *Pt 1, Ch 5 Guidelines for Classification using Risk Assessment Techniques to Determine Performance Standards*, and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.

1.1.7 When cargo is carried in a cargo containment system requiring a complete or partial secondary barrier:

(a) at temperatures below –10°C, hold spaces shall be segregated from the sea by a double bottom; and
(b) at temperatures below –55°C, the ship unit shall also have a longitudinal bulkhead forming side tanks.

1.1.8 Arrangements shall be made for sealing the weather decks in way of openings for cargo containment systems.

1.1.9 Cargo tank holds are to be separated from each other by single bulkheads of all welded construction. Where, however, the cargo design temperature as defined in *Pt 11, Ch 4, 1.1 Definitions* is below –55°C, cofferdams are to be adopted unless the cargo is carried in independent tanks and alternative arrangements are made to ensure the bulkhead cannot be cooled to below –55°C. Cofferdams may be used as ballast tanks, subject to approval by Lloyd's Register (LR).

1.2 Accommodation, service and machinery spaces and control stations

1.2.1 No accommodation space, service space (except cargo service spaces, *see Pt 11, Ch 3, 1.2 Accommodation, service and machinery spaces and control stations 1.2.2* or topsides service spaces) or control station shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces (except cargo and topsides service spaces) or control stations that face the cargo area shall be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship unit having a containment system requiring a secondary barrier. Cargo, topsides and turret service spaces (i.e. workshops, store rooms, etc.) and machinery spaces located above the cargo storage areas, which are impacted by hazardous areas, are to be in accordance with the requirements of*Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.2.2 Cargo service spaces as defined in *Pt 11, Ch 1, 1.3 Definitions* may be situated within cargo areas, provided all other relevant requirements of these Rules are complied with.

1.2.3 In order to guard against the danger of hazardous vapours, due consideration should be given to the location of air intakes/outlets and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements. *See Pt 7, Ch 2 Hazardous Areas and Ventilation*, regarding the air intakes/outlets and openings to enclosed non hazardous areas.

1.2.4 As far as practicable, access doors or other openings should not be provided between a non-hazardous space and a hazardous area or space, or between Zone 2 and a Zone 1 space, as defined in *Pt 11, Ch 10 Electrical Installations*. Where such openings are necessary, access from the accommodation, service spaces, machinery spaces or any other defined non hazardous enclosed areas on topsides, deck, turret or within the hull are to be in compliance with *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.2.5 Entrances, air inlets and openings to accommodation spaces and hull spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4 per cent of the load line length, L, as defined in *Pt 11, Ch 1, 1.3 Definitions* of the ship unit but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.

(a) Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above shall be of the fixed (non-opening) type. Wheelhouse windows for navigational purposes may be non-fixed and wheelhouse doors may be located within the above limits so long as they are designed in a manner such that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.
(b) Access to forecastle spaces containing sources of ignition may be permitted through door access facing the cargo area, provided the doors are either located a suitable distance outside hazardous areas as defined in *Pt 11, Ch 10 Electrical Installations* or are in accordance with the requirements of *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.2.6 Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in *Pt 11, Ch 3, 1.2 Accommodation, service and machinery spaces and control stations 1.2.5*, except wheelhouse windows for navigational purposes where applicable, shall be constructed to at least A-60 class. Wheelhouse windows for navigational purposes shall be constructed to at least A-0 class (for external fire load). Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type. It should be noted that the above minimum class of windows should be confirmed for their suitability within the installation Fire and Explosion Evaluation (FEE). If necessary, higher rated windows or alternative designs without windows may be required dependent upon the findings of the FEE.

1.2.7 All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. For toxic gases, they shall be operated from inside the space. Air intakes and outlets and the protection against gas ingress into all accommodation spaces, service spaces and control stations are to be in accordance with the requirements of *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas* and *Pt 7, Ch 2, 6.1 General requirements*.

1.2.8 Control rooms and machinery spaces of turret systems may be located in the cargo area forward or aft of cargo tanks in ship units with such installations. Access to such spaces containing sources of ignition may be permitted through doors facing the cargo area, provided the doors are located outside hazardous areas or access is in accordance with the requirements of *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.2.9 Any topsides or turret service spaces or machinery spaces shall generally be treated for the purpose of fire containment according to SOLAS Regulation *2.4 Tankers*. However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy.

1.2.10 Arrangements of any topsides or turret service spaces or machinery spaces should ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in each service space, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

1.3 Cargo machinery spaces and turret compartments

1.3.1 Cargo machinery spaces shall be situated above the weather deck and located within the cargo area. Cargo machinery spaces and turret compartments shall be treated as cargo pump rooms for the purpose of fire protection according to SOLAS

Regulation *2.4 Tankers*, and for the purpose of prevention of potential explosion according to SOLAS *5.10 Protection of cargo pump-rooms*.

1.3.2 When cargo machinery spaces are located at the after end of the aftermost hold space or at the forward end of the forwardmost hold space, the limits of the cargo area, as defined in *Pt 11, Ch 1, 1.3 Definitions*, shall be extended to include the cargo machinery spaces for the full breadth and depth of the ship unit and the deck areas above those spaces.

1.3.3 Where the limits of the cargo area are extended by *Pt 11, Ch 3, 1.3 Cargo machinery spaces and turret compartments 1.3.2*, the bulkhead that separates the cargo machinery spaces from accommodation and service spaces, control stations and machinery spaces of category A shall be located so as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

1.3.4 Cargo compressors and cargo pumps may be driven by electric motors in an adjacent non-hazardous space separated by a bulkhead or deck if the seal around the bulkhead penetration ensures effective gas-tight segregation of the two spaces. Where these cargo compressors and cargo pumps are located in hazardous areas, they are to comply with *Pt 7, Ch 2, 5.1 General 5.1.2*. Alternatively the use of motor compressor and motor pump sets with the complete package certified for use in hazardous areas is acceptable.

1.3.5 Arrangements of cargo machinery spaces and turret compartments should ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in cargo machinery spaces, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

1.3.6 All valves necessary for cargo handling shall be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.

1.3.7 Turret compartments shall be designed to retain their structural integrity in case of explosion or uncontrolled high pressure gas release (overpressure and/or brittle fracture), the characteristics of which shall be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure-relieving devices. *See also Pt 10, Ch 2, 5.2 Blast condition*.

1.4 Cargo control rooms

1.4.1 Any cargo control room shall be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations provided the following conditions are complied with:

(a) the cargo control room is a non-hazardous area;

- (i) if the entrance complies with *Pt 11, Ch 3, 1.2 Accommodation, service and machinery spaces and control stations 1.2.5*, the control room may have access to the spaces described above;
- (ii) if the entrance does not comply with *Pt 11, Ch 3, 1.2 Accommodation, service and machinery spaces and control stations 1.2.5* the cargo control room shall have no access to the spaces described above and the boundaries for such spaces shall be insulated to at least A-60 class or higher. It should be noted that the minimum fire class of a cargo control room's boundaries should be confirmed for their suitability within the installation Fire and Explosion Evaluation (FEE). If necessary, higher rated fire boundaries may be required, dependent upon the findings of the FEE.

1.4.2 If the cargo control room is designed to be a non-hazardous area, instrumentation should, as far as possible, be by indirect reading systems and shall in any case be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detection system within the cargo control room will not cause the room to be classified as a hazardous area, if installed in accordance with *Pt 11, Ch 13, 1.6 Gas detection 1.6.10*.

1.4.3 If the cargo control room for ship units carrying flammable cargoes is classified as a hazardous area, sources of ignition shall be excluded and any electrical equipment shall be installed in accordance with *Pt 11, Ch 10 Electrical Installations* and *Pt 7, Ch 2, 8 Electrical equipment for use in explosive gas atmospheres*.

1.5 Access to spaces in the cargo area

1.5.1 Visual inspection of at least one side of the inner hull structure shall be possible without the removal of any fixed structure or fitting. If such a visual inspection, whether or not combined with those inspections required in *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.2* or *Pt 11, Ch 4 Cargo Containment*, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel oil tank boundary wall.

1.5.2 Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

1.5.3 Arrangements for hold spaces, void spaces, cargo tanks and other spaces defined as hazardous areas in *Pt 11, Ch 10 Electrical Installations* and *Pt 7, Ch 2, 2 Classification of hazardous areas*, shall be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and shall also allow for the evacuation of injured and/or unconscious personnel. Such arrangements shall comply with the following:

(a) Access shall be provided:

- (i) To all cargo tanks, access shall be direct from the weather deck.
- (ii) Access through horizontal openings, hatches or manholes, the dimensions shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space the minimum clear opening shall be not less than 600 mm × 600 mm; and
- (iii) Access through vertical openings or manholes providing passage through the length and breadth of the space, the minimum clear opening shall be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.
- (iv) Circular access openings to Type C tanks shall have a diameter of not less than 600 mm.

(b) The dimensions referred to in (a)(ii) and (a)(iii) may be decreased if the requirements of *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.3* can be met to the satisfaction of the Administration.

(c) Where cargo is carried in a containment system requiring a secondary barrier the requirements of (a)(ii) and (a)(iii) do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non hazardous area.

(d) Access required for inspection shall be provided as follows:

- (i) Designated access through structures below and above cargo tanks shall have at least the cross sections as required by (a)(iii)

(e) For the purpose of *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.1* or *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.2* the following shall apply:

- (i) Where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc. the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface (e.g. for a Type C tank) or 600 mm for a flat tank surface (e.g. for a Type A tank). (*See Figure 3.1.1 Minimum passage clearance for tank inspection in way of ship structural members*).

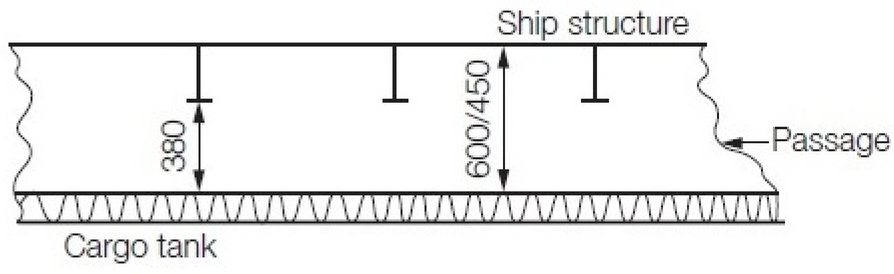


Figure 3.1.1 Minimum passage clearance for tank inspection in way of ship structural members

- (ii) Where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the face plate of the structure, whichever is the larger. *See Figure 3.1.2 Minimum visibility clearance for tank inspection in way of ship structural members*.

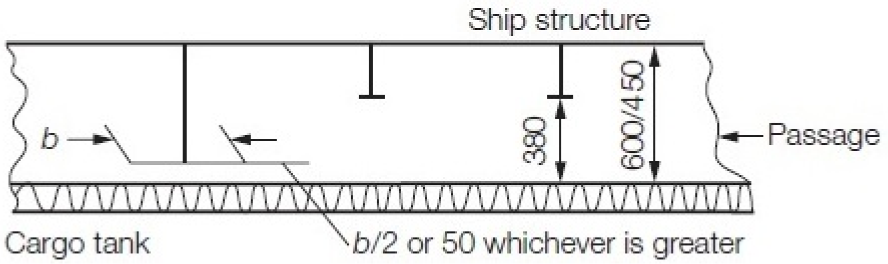


Figure 3.1.2 Minimum visibility clearance for tank inspection in way of ship structural members

(iii) For inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm, *see Figure 3.1.3 Minimum passage clearance for tank inspection between surfaces*. Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface.

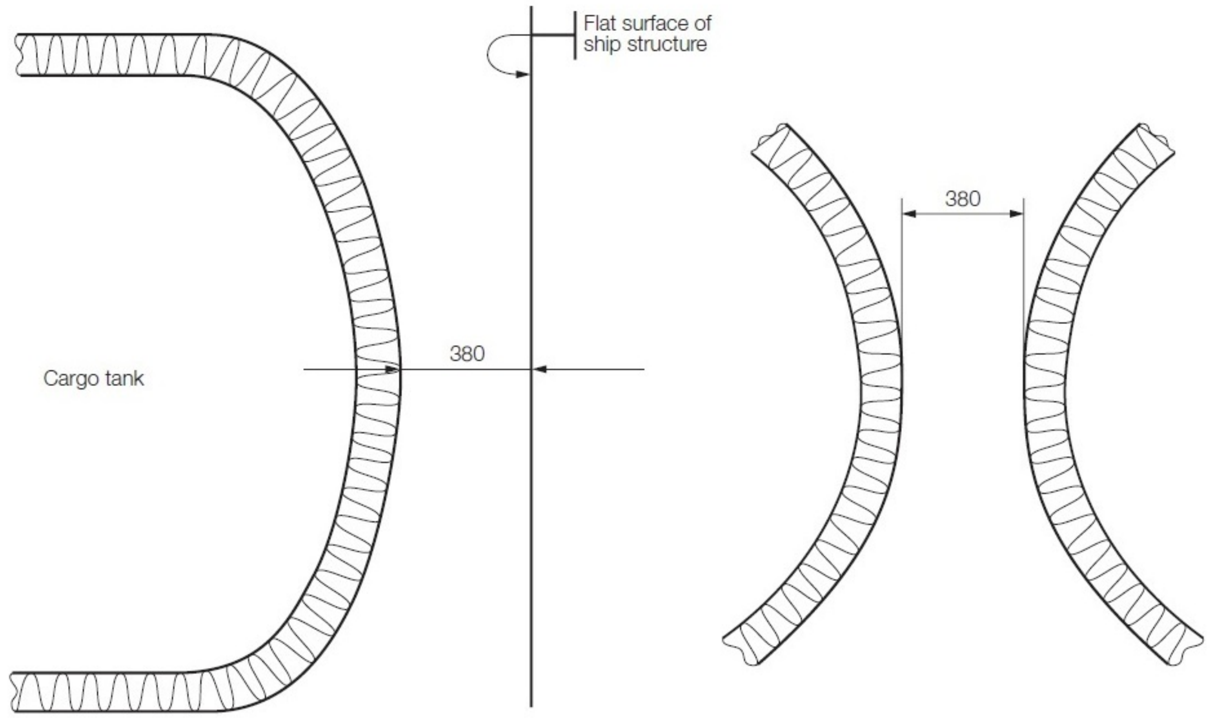


Figure 3.1.3 Minimum passage clearance for tank inspection between surfaces

(iv) For inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted a clearance of at least 450 mm shall be provided for access. *See Figure 3.1.4 Minimum access clearance in way of fixed access ladders*.

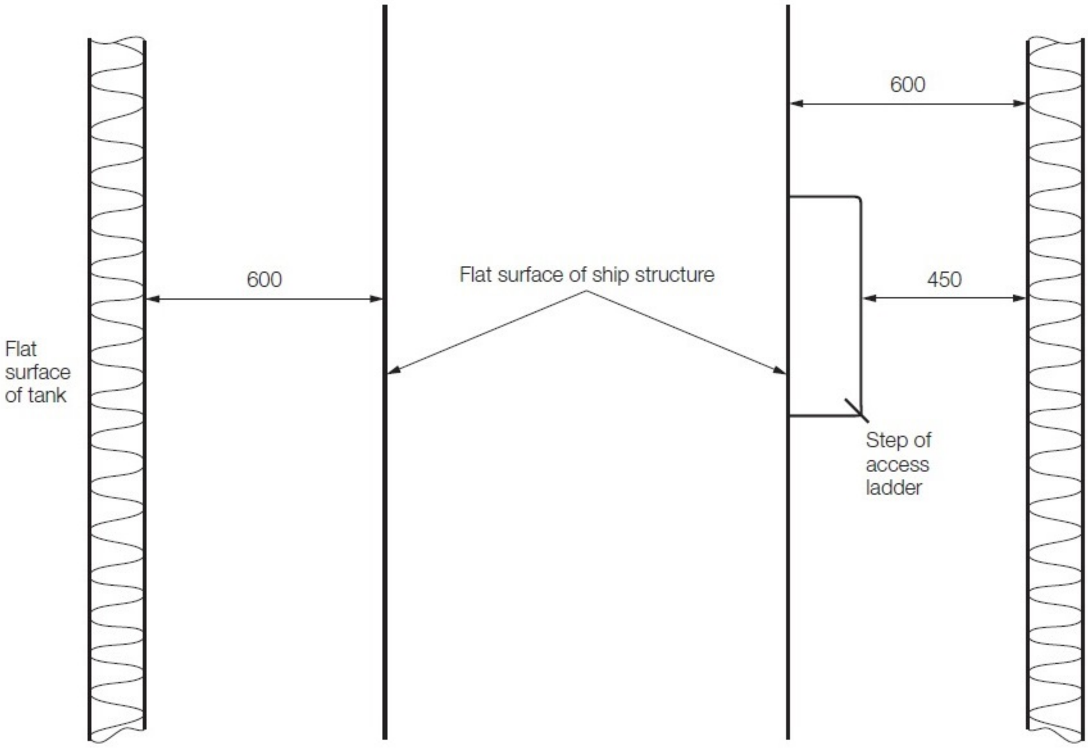


Figure 3.1.4 Minimum access clearance in way of fixed access ladders

(v) The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in *Figure 3.1.5 Minimum distances between cargo tank sump and adjacent double bottom structure in way of a section well*. If there is no suction well the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm.

NOTE

Figure 3.1.5 Minimum distances between cargo tank sump and adjacent double bottom structure in way of a section well shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm.

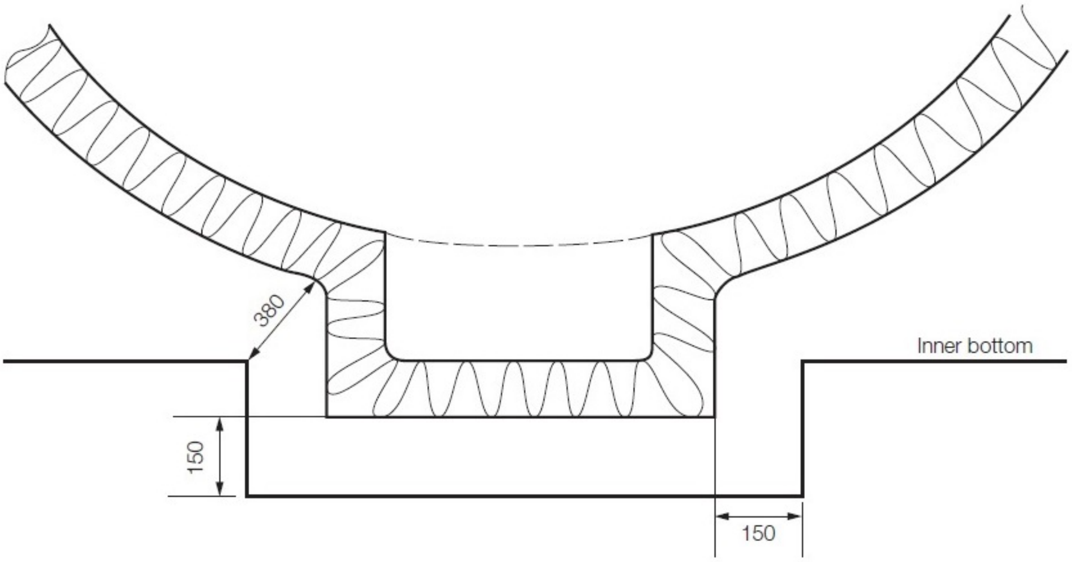


Figure 3.1.5 Minimum distances between cargo tank sump and adjacent double bottom structure in way of a section well

(vi) The distance between a cargo tank dome and deck structures shall not be less than 150 mm. *See Figure 3.1.6 Minimum distance between cargo tank dome and deck structure*.

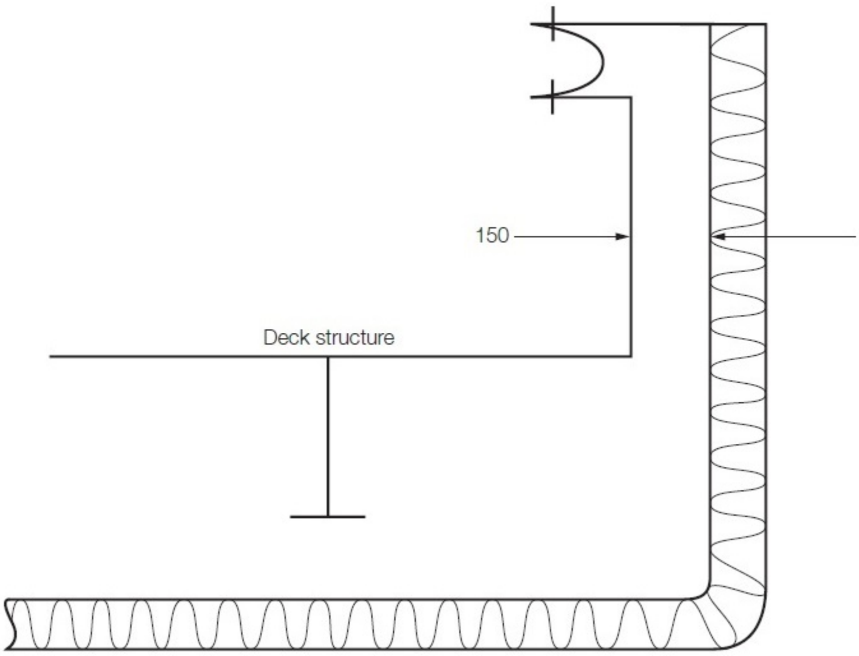


Figure 3.1.6 Minimum distance between cargo tank dome and deck structure

(vii) Fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints (e.g. anti-pitching, anti-rolling and anti-flotation chocks), cargo tank insulation etc. This staging shall not impair the clearances specified in (i) to (v) .

(viii) If fixed or portable ventilation ducting is to be fitted in compliance with *Pt 11, Ch 12, 1.2 Spaces not normally entered* (i) to (v), such ducting shall not impair the distances required under *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.3* (i) to (iv) .

1.5.4 In general, the requirements for minimum clear opening given in *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.3* (a)(ii) and (a)(iii) *Pt 11, Ch 3, 1.5 Access to spaces in the cargo area 1.5.3* are also to be adhered to for spaces separated by a single gastight steel boundary from a hold space where cargo is carried in a cargo containment system requiring a secondary barrier. Reference is made to IACS *Interpretations of the IMO Code for the Construction and Equipment of Ships carrying Liquefied Gases in Bulk No. GC6.*

For ship units complying with the requirements for Type A independent tanks, manholes will not be permitted through the secondary barrier, except through the upper deck in regions which are above the predicted surface of the cargo assuming total failure of the cargo tank and the ship unit at 30 degrees heel port or starboard. Alternative structural arrangement will be specially considered.

1.5.5 As far as practicable, access from the open weather deck to non-hazardous areas are to be located outside hazardous areas as defined in *Pt 11, Ch 10 Electrical Installations*. Where it is not possible to located a weather deck non hazardous enclosure access doorway in a non hazardous area, access is to be in compliance with *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.5.6 Turret compartments shall be arranged with two independent means of access/egress. The access/egress routes are to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. A single escape route may be accepted for turret compartments where the maximum travel distance to the door is 5 m or less.

1.5.7 Access from a hazardous area below the hull weather deck to a non-hazardous area should be avoided. However, where it is not practicable access is to be in compliance with *Pt 7, Ch 2, 4 Enclosed and semi-enclosed spaces with access to a hazardous area*.

1.6 Airlocks

1.6.1 Access between hazardous areas on the open weather deck and non-hazardous spaces shall be by means of an airlock. This shall consist of two self closing, substantially gastight, steel doors without any holding back arrangements, capable of maintaining the over pressure, at least 1,5 m but no more than 2,5 m apart. The airlock space shall be artificially ventilated from a non-hazardous area and maintained at an overpressure to the hazardous area on the weather deck.

1.6.2 Where spaces are protected by pressurisation, the ventilation is to be designed and installed in accordance with *Pt 7, Ch 1, 5 Protection against gas ingress into safe areas* and *Pt 7, Ch 2, 6.1 General requirements* or an equivalent National or Internationally recognised Standard, submitted to LR for approval.

1.6.3 The relative air pressure within the non hazardous enclosure is to be continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at a manned control station.

1.6.4 For electrical equipment that is located in enclosed non hazardous spaces, is not certified for operation in a Zone 1 hazardous area and does not have to remain operational during catastrophic conditions (i.e. major hydrocarbon release scenarios), consideration shall be given to de-energising this equipment in case of confirmed loss of overpressure in the space. If the flammable gas is subsequently detected within the area all non emergency electrical items of equipment are to be de-energised immediately.

1.6.5 Electrical equipment for manoeuvring, anchoring and mooring as well as emergency fire pumps that are located in spaces protected by airlocks shall be of a certified safe type.

1.6.6 The airlock space shall be monitored for cargo vapours, *see also Pt 11, Ch 13, 1.6 Gas detection 1.6.2*.

1.6.7 Subject to the requirements of the International Convention on Load Lines as amended, the door sill shall not be less than 300 mm in height.

1.6.8 Air locks are to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed.

1.7 Bilge, ballast and fuel oil arrangements

1.7.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier, suitable drainage arrangements for the hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.

1.7.2 Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The suction shall not lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.

1.7.3 The hold or interbarrier spaces of Type A independent tank ship units shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements shall provide for the return of any cargo leakage to the liquid cargo piping.

1.7.4 Arrangements referred to in *Pt 11, Ch 3, 1.7 Bilge, ballast and fuel oil arrangements 1.7.3* shall be provided with a removable spool piece.

1.7.5 Ballast spaces, including wet duct keels used as ballast piping, fuel oil tanks and non-hazardous spaces, may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps and the discharge from the pumps is led directly overboard with no valves or manifolds in either line that could connect the line from the duct keel to lines serving non-hazardous spaces. Pump vents shall not be open to machinery spaces.

1.8 Tandem and side-by-side loading and unloading arrangements

1.8.1 Subject to the requirements of this Section and *Pt 11, Ch 5 Process Pressure Vessels and Liquids, Vapour and Pressure Piping Systems and Offshore Arrangements*, cargo piping may be arranged to permit tandem (bow or stern) and side-by-side loading and unloading.

1.8.2 Portable arrangements shall not be permitted.

1.8.3 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and controls stations shall not face the cargo connection location of the unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a distance of at least 4 per cent of the length of the ship unit, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo connection location of the unloading arrangements. This distance need not exceed 5 m.

(a) Windows and sidescuttles facing the connection location of the shuttle tanker and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type.
(b) In addition, during the use of the unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side should be kept closed.

1.8.4 Deck openings and air inlets and outlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of the unloading arrangements.

1.8.5 Fire-fighting arrangements for the unloading areas shall generally be in accordance with *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* (d) and *Pt 11, Ch 11, 1.4 Dry chemical powder fire-extinguishing systems*. However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy. Full details of the proposals are to be submitted for consideration.

1.8.6 Means of communication between the cargo control station and the connection location of the shuttle tanker shall be provided and where applicable certified for use in hazardous areas.

1.8.7 Hull, hull weather deck and liquefied gas offloading arrangements shall generally be treated for the purpose of fire containment according to SOLAS Regulation *2.4 Tankers* and for fire mitigation according to*Pt 11, Ch 11 Fire Prevention and Extinction* . However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy.

■ *Section 1*
General

1.1 Definitions

1.1.1 **Cold spot.** A cold spot is a part of the hull or thermal insulation surface where a localised temperature decrease occurs under loaded condition with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/temperature control systems required in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* .

1.1.2 **Design vapour pressure.** The design vapour pressure 'P_o' is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.1.3 **Cargo design temperature**. The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or stored in the cargo tanks.

1.1.4 **Independent tanks** are self-supporting; they do not form part of the hull of the ship unit and are not essential to the hull strength. There are three categories of independent tank, which are referred to in *Pt 11, Ch 4, 6.2 Type B independent tanks* and *Pt 11, Ch 4, 6.3 Type C independent tanks* .

1.1.5 **Membrane tanks** are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in *Pt 11, Ch 4, 6.4 Membrane tanks*.

1.1.6 **Integral tanks** are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in *Pt 11, Ch 4, 6.5 Integral tanks*.

1.1.7 **Semi-membrane tanks** are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure. Semi-membrane tanks are covered in *Pt 11, Ch 4, 6.6 Semi-membrane tanks*.

1.1.8 In addition to the definitions in *Pt 11, Ch 1, 1.3 Definitions* , the definitions given in this Chapter shall apply throughout this Part.

1.1.9 **Recovery Duration (RD).** When a secondary barrier, or a partial secondary barrier, is required an RD is defined as the time (in days) necessary to make the ship unit safe, secure and ready for repair after a leak through the primary barrier is detected.

In the calculation of the RD, due account shall be taken of liquid evaporation, rate of leakage, access to external facilities such as shuttle tankers, pumping capacity and other relevant factors such as operational situations, human factors, delays due to weather conditions.

The required RD and the associated safety factor shall be advised to LR at the commencement of the project.

1.2 Application

1.2.1 Unless otherwise specified in *Pt 11, Ch 4, 6 Tank types*, the requirements of *Pt 11, Ch 4, 2 Cargo containment* to *Pt 11, Ch 4, 5 Materials and construction* shall apply to all types of tanks, including those covered in *Pt 11, Ch 4, 7 Guidance*.

Section 2
Cargo containment

2.1 Functional requirements

2.1.1 Details of the proposed design of cargo containment systems are to be submitted for consideration, and it is recommended this is done at as early a stage as possible. For a description of LR's system of approval, refer to the Marine Survey Guidance System. *See also Pt 11, Ch 1, 1.4 Alternative arrangements*.

2.1.2 The design life of the cargo containment system shall not be less than the design life of the ship unit.

2.1.3 Cargo containment systems shall be designed with site-specific environmental loads for the proposed area of operation. The cargo containment system shall also be designed for all transit conditions as applicable to the operational philosophy of the unit; this includes delivery voyages and sail-away disconnect conditions.

2.1.4 Cargo containment systems shall be designed with suitable safety margins:

(a) to withstand, in the intact condition, the environmental conditions anticipated for the cargo containment system's design life and the loading conditions appropriate for them, which include loads derived for the following scenarios: on-site operation, inspection/maintenance, transit/disconnect and accidental. The most onerous loading conditions are to be considered.

(b) that are appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, ageing and construction tolerances.

2.1.5 The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling, and fatigue. The specific design conditions that should be considered for the design of each cargo containment system are given in *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.5 Integral tanks*. There are three main categories of design conditions:

(a) **On-site operation design conditions** – The cargo containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

- Internal pressure.
- External pressure.
- Dynamic loads due to the motion of the ship unit.
- Thermal loads.
- Sloshing loads.
- Loads corresponding to deflections of the ship unit.
- Tank and cargo weight with the corresponding reaction in way of supports.
- Insulation weight.
- Loads in way of towers and other attachments.
- Test loads.

The loads are to be calculated at a return period of 100 years.

The relevant acceptance criteria and allowable stresses are to be in accordance with *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.5*, *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.3*, *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3*, *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.3*, *Pt 11, Ch 4, 6.5 Integral tanks* and *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.2* (a) as appropriate.

(b) **Fatigue design conditions** – The cargo containment system structure and its structural components shall not fail under accumulated cyclic loading.

(c) **Accident design conditions** – The cargo containment system shall provide the indicated response to each of the following accident conditions (accidental or abnormal events), addressed in this Part:

- Collision – the cargo containment system shall be protectively located in accordance with *Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.1* and withstand the collision loads specified in *Pt 11, Ch 4, 3.5 Accidental loads 3.5.3* without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.
- Fire – The cargo containment systems shall sustain without rupture the rise in internal pressure specified in 8.4.1 under the fire scenarios envisaged therein.

- Flooded compartment causing buoyancy on tank – The anti-flotation arrangements, for independent tanks, shall sustain the upward force, specified in *Pt 11, Ch 4, 3.5 Accidental loads 3.5.2* and there should be no endangering plastic deformation to the hull.
- Loss of heading control – when applicable, the effect of loss of heading control on the cargo containment system shall be considered in the design as specified in *Pt 11, Ch 4, 3.5 Accidental loads*

The relevant acceptance criteria and allowable stresses are to be in accordance with *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.6*, or *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.2*, or *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.4*, or *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.2*, or *Pt 11, Ch 4, 6.5 Integral tanks 6.5.2* as appropriate.

2.1.6 Measures shall be applied to ensure that scantlings required meet the structural strength provisions and will be maintained throughout the design life. Measures include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting.

Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature, LR may require a suitable corrosion allowance.

2.1.7 In addition to the loading conditions defined in *Pt 11, Ch 4, 2.1 Functional requirements 2.1.5*, a 10 000 year return period design condition is to be considered defined as follows:

10 000 year return period design condition – The cargo containment system integrity and its structural components shall withstand 10 000 year return period loads without loss of containment integrity and without hydrocarbon release. The design shall take into account proper combinations of the following loads:

- Internal pressure.
- External pressure.
- Dynamic loads due to the motion of the ship unit.
- Thermal loads.
- Sloshing loads.
- Loads corresponding to deflections of the ship unit.
- Tank and cargo weight with the corresponding reaction in way of supports.
- Insulation weight.
- Loads in way of towers and other attachments.

The relevant acceptance criteria and allowable stresses are to be in accordance with *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.3*, *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.3* (a)(iv), *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3* (b), 6.4.3 and *Pt 11, Ch 4, 6.5 Integral tanks 6.5.2* (b) as appropriate.

2.1.8 In areas where excessive corrosion might be expected, a corrosion addition may be required if means of protection are not installed.

2.1.9 An inspection/survey plan for the cargo containment system shall be developed and approved at the time of build. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system's life and in particular all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment shall be designed and built to ensure safety during operations, inspection and maintenance (*see Pt 11, Ch 3, 1.5 Access to spaces in the cargo area*).

2.2 Cargo containment safety principles

2.2.1 The containment systems shall be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the structure of the ship unit to an unsafe level.

2.2.2 However, the size and configuration or arrangement of the secondary barrier can be reduced where an equivalent level of safety can be demonstrated in accordance with the requirements of *Pt 11, Ch 4, 2.2 Cargo containment safety principles 2.2.3* to *Pt 11, Ch 4, 2.2 Cargo containment safety principles 2.2.5* as applicable.

2.2.3 Cargo containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low, but where the possibility of leakages through the primary barrier cannot be excluded, shall be

equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages.

The arrangements shall comply with the following requirements:

(a) Failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken.
(b) Failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.

2.2.4 No secondary barrier is required for cargo containment systems, e.g. Type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.

2.2.5 No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above –10°C.

2.3 Secondary barriers in relation to tank types

2.3.1 Secondary barriers in relation to the tank types defined in *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks* shall be provided in accordance with *Table 4.2.1 Secondary barriers in relation to tank*.

Table 4.2.1 Secondary barriers in relation to tank

Cargo temperature at atmospheric pressure	–10°C and above	Below –10°C down to –55°C	Below –55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral		Tank type not normally allowed, *see* Note 1	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier *see* Note 2	
Independent			
Type A		Complete secondary barrier	
Type B		Partial secondary barrier	
Type C		No secondary barrier required	

NOTES

1. A complete secondary barrier should normally be required if cargoes with a temperature at atmospheric pressure below –10°C are permitted in accordance with *Pt 11, Ch 4, 6.5 Integral tanks 6.5.1*

2. In the case of semi-membrane tanks that comply in all respects with the requirements applicable to Type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

2.4 Design of secondary barriers

2.4.1 Where the cargo temperature at atmospheric pressure is not below –55°C, the hull structure may act as a secondary barrier based on the following:

(a) the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by *Pt 11, Ch 4, 5.2 Construction processes 5.2.1* (d); and
(b) the design shall be such that this temperature will not result in unacceptable hull stresses.

2.4.2 The design of the secondary barrier shall be such that:

(a) it is capable of containing any envisaged leakage of liquid cargo for the RD, as specified in *Pt 11, Ch 4, 4.3 Design conditions 4.3.3* (f) , unless different project-specific requirements apply, taking into account the load spectrum referred to in *Pt 11, Ch 4, 4.3 Design conditions*. Project-specific requirements are to be submitted for consideration.

(b) physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa.

(c) failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers.

(d) it is capable of being periodically checked for its effectiveness by means acceptable to LR of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with LR.

(e) The methods required in *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2* shall be approved by LR and shall include, where applicable to the test procedure:

  (i) Details on the size of defect acceptable and the location within the secondary barrier, before its liquid tight effectiveness is compromised.

  (ii) Accuracy and range of values of the proposed method for detecting defects in *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2*.

  (iii) Scaling factors to be used if full scale model testing is not undertaken.

  (iv) Effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test.

(f) The secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

(g) Proposals for the periodical examination of the secondary barrier are to be submitted for consideration.

2.5 Partial secondary barriers and primary barrier small leak protection system

2.5.1 Partial secondary barriers shall be used with a small leak protection system and meet all the requirements in *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2*. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

2.5.2 The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in *Pt 11, Ch 4, 4.3 Design conditions 4.3.3* (f), after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

2.5.3 The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.

2.6 Supporting arrangements

2.6.1 The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in *Pt 11, Ch 4, 3.2 Permanent loads* to *Pt 11, Ch 4, 3.5 Accidental loads*, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

2.6.2 Tank supporting arrangements are generally to be located in way of the primary support structure of the tank and the hull of the ship unit. Steel seatings are to be arranged, where possible, on both the inner bottom and underside of the cargo tank so as to ensure an effective distribution of the transmitted load and reactions into the cargo tanks and double bottom structure.

2.6.3 The strength of supporting arrangements is to be verified by direct calculation.

2.6.4 Anti-flotation arrangements shall be provided for independent tanks and be capable of withstanding the loads defined in *Pt 11, Ch 4, 3.5 Accidental loads 3.5.2* without plastic deformation likely to endanger the hull structure.

2.6.5 Supports and supporting arrangements shall withstand the loads defined in *Pt 11, Ch 4, 3.3 Functional loads 3.3.10* and *Pt 11, Ch 4, 3.5 Accidental loads* , but these loads need not be combined with each other or with wave-induced loads.

2.6.6 An adequate clearance is to be provided between the anti-flotation chocks and the hull of the ship unit in all operational conditions.

2.6.7 The effects on the supporting arrangements of the 10 000 year return period wave loading are to be considered as follows:

- Resulting acceleration loadings.
- Hull interaction loadings.

Calculations and analyses are to be performed to show that there would be no gross failure of the supporting arrangements in this event as prescribed above for each tank type.

2.7 Associated structure and equipment

2.7.1 Cargo containment systems are to be designed for the loads imposed by associated structure and equipment. This includes pump towers, cargo domes, cargo pumps and piping, stripping pumps and piping, inert gas piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges).

2.8 Thermal insulation

2.8.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable (*see Pt 11, Ch 4, 5.1 Materials 5.1.2*) and to limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* .

2.8.2 In determining the insulation performance, due regard should be paid to the amount of the acceptable boil-off in association with the liquefaction or reliquefaction plant on board, gas consumers if present or other temperature control system.

■ *Section 3*
Design Loads

3.1 General

3.1.1 This Section defines the design loads to be considered with regard to the requirements in *Pt 11, Ch 4, 4.1 General*, *Pt 11, Ch 4, 4.2 Structural analyses* and *Pt 11, Ch 4, 4.3 Design conditions*. This includes:

- Load categories (permanent, functional, environmental and accidental) and the description of the loads.

The extent to which these loads shall be considered depends on the type of tank, and is more fully detailed in the following paragraphs.

Tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.

3.2 Permanent loads

3.2.1 **Gravity loads**

The weight of tank, thermal insulation, loads caused by towers and other attachments.

3.2.2 **Permanent external loads**

Gravity loads of structures and equipment acting externally on the tank.

3.3 Functional loads

3.3.1 Loads arising from the operational use of the tank system shall be classified as functional loads.

All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered.

As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

- Internal pressure.
- External pressure.
- Thermally induced loads.
- Vibration.
- Interaction loads.
- Loads associated with construction and installation.
- Test loads.
- Static heel loads.
- Weight of cargo.

3.3.2 **Internal pressure**

(a) In all cases, including (b) below, P_o shall not be less than MARVS.

(b) For cargo tanks where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_o shall not be less than the gauge vapour pressure of the cargo at a temperature equal to the maximum daily mean ambient air temperature for the unit's proposed area of operation based on the 100 year average return period. The ambient temperature is to be rounded up to the nearest degree Celsius, and not to be taken as less than 45°C unless agreed by LR.

(c) Subject to special consideration by the Administration and to the limitations given in *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks*, for the various tank types, a vapour pressure P_h higher than P_o may be accepted for site-specific conditions where dynamic loads are reduced.

(d) The internal pressure P_{eq} results from the vapour pressure P_o or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads. Guidance formulae for associated dynamic liquid pressure P_{gd} are given in *Pt 11, Ch 4, 7.1 Guidance Notes for Chapter 4 7.1.1*.

3.3.3 **External pressure**

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

3.3.4 **Thermally induced loads**

Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below –55°C.

Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses. *See Pt 11, Ch 7, 1.2 Design of systems* .

3.3.5 **Vibration**

The potentially damaging effects of vibration on the cargo containment system shall be considered.

3.3.6 **Interaction loads**

The static component of loads resulting from interaction between cargo containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered.

3.3.7 **Loads associated with construction and installation**

Loads or conditions associated with construction and installation shall be considered, e.g. lifting.

3.3.8 **Test loads**

Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks*.

3.3.9 **Static heel loads**

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° shall be considered.

3.3.10 **10 000 year return period loading**

The effects on the containment system of the 10 000 year return period wave loading are to be considered.

3.3.11 **Other loads**

Any other loads not specifically addressed, which could have an effect on the cargo containment system, shall be taken into account.

3.4 Environmental loads

3.4.1 Environmental loads are defined as those loads on the cargo containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

3.4.2 **Loads due to the motions of the ship unit**

The determination of dynamic loads shall take into account the long-term distribution of the motions of the ship unit in irregular seas, which the ship unit will experience during its operating life. Account may be taken of the reduction in dynamic loads due to heading control.

(a) The motions of the ship unit shall include surge, sway, heave, roll, pitch and yaw. The accelerations, derived from site-specific wave data and the heading analysis, acting on tanks, shall be estimated at their centre of gravity and include the following components:

- vertical acceleration: motion accelerations of heave, pitch and possibly roll (normal to the base of the ship unit);
- transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll;
- longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

(b) Methods to predict accelerations due to ship motion shall be proposed to LR and approved by LR.

(c) Guidance formulae for acceleration components are given in *Pt 11, Ch 4, 7.1 Guidance Notes for Chapter 4 7.1.2* .

(d) The determination of the dynamic loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the cargo containment system at the site-specific location, taking into account the following service-related factors:

site-specific environmental loads including relevant non-linear effects;
mooring system and riser loads;
unit orientation and wave loading directions;
long-term service effects at a fixed location;
range of tank loading conditions, including empty tanks required for on-station surveys;
potential relocations if applicable.

The actual form and weight distribution of the unit and the longitudinal and transverse locations of the tanks are to be taken into account.

3.4.3 **Dynamic interaction loads**

Account shall be taken of the dynamic component of loads resulting from interaction between cargo containment systems and the hull structure, including loads from associated structures and equipment.

3.4.4 **Sloshing loads**

The sloshing loads on a cargo containment system and internal components, induced by any of the site-specific motions referred to in *Pt 11, Ch 4, 3.4 Environmental loads 3.4.2*, shall be evaluated based on allowable filling levels.

When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

Where loading conditions are proposed, including one or more partially filled tanks, calculations or model tests will be required to show that the resulting loads and pressure are within acceptable limits for the scantlings of the tanks. Additionally, investigations should be made to ensure that the internal structure, equipment and pipework exposed to fluid motion are of adequate strength.

If the liquefied gas storage tanks are to have no filling restrictions, the capacity of the cargo containment system to resist the greatest predicted sloshing pressures is to be assessed for fill heights representative of all filling levels in accordance with this Section.

If filling restrictions are contemplated, the capacity of the cargo containment system to resist sloshing predicted pressures needs to be assessed only for fill heights representative of the permitted filling ranges. In this case, the filling restrictions are to be stated in the approved Loading Manual.

3.4.5 **Snow and ice loads**

Snow and icing shall be considered, if relevant.

3.4.6 **Loads due to operation in ice conditions**

Loads due to operation in ice conditions shall be considered for units intended for such service. The effects on the containment system due to additional topside weight as a result of ice accretion, and ice collisions against the hull should be considered, *see also Pt 3, Ch 6 Units for Transit and Operation in Ice*.

3.5 Accidental loads

3.5.1 Accidental loads are defined as loads that are imposed on a cargo containment system and its supporting arrangements under abnormal and unplanned conditions.

3.5.2 **Loads due to flooding**

For independent tanks, loads caused by the buoyancy of an empty tank in a hold space, flooded to the summer load draught, shall be considered in the design of the anti-flotation chocks and the supporting hull structure.

3.5.3 **Collision loads**

Where collision is defined by the Owner as a credible accidental load case, the requirements in this section are to be followed in order to assess the chocks and supports of the tanks.

Assessment against collision is to be in accordance with *Pt 4, Ch 3, 4.16 Accidental loads*.

All static loads are to be applied. Environmental loads need not be applied. Acceleration resulting from the collision is to be applied to all of the mass of the model including the cargo in the tanks.

3.5.4 **Loss of heading control**

Where stern thrusters or other means of heading control are fitted to weathervaning units then the effect of any single failure of the heading control system on the cargo containment system and its supporting arrangements is to be considered (*see Pt 3, Ch 10 Positional Mooring Systems*for thruster assisted mooring systems).

■ *Section 4*
Structural Integrity

4.1 General

4.1.1 The structural design shall ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This should take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.

4.1.2 The structural integrity of cargo containment systems can be demonstrated by compliance with *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks*, as appropriate for the cargo containment system type.

4.1.3 The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks* shall be demonstrated by compliance with *Pt 11, Ch 4, 8.1 Design for novel concepts* to ensure that the overall level of safety provided in this chapter is maintained.

4.2 Structural analyses

4.2.1 **Analysis**

The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.

Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.

When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.

Where direct calculation procedures are adopted, the assumptions made and other details of the calculations are to be submitted.

4.2.2 **Load scenarios**

For each location or part of the cargo containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.

The most onerous load scenarios for all relevant phases of the life-cycle shall be considered. Loads during construction/handling, installation, on-site operation, inspection/maintenance including testing and in transit/disconnect conditions shall be considered, as applicable.

4.2.3 When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses shall be calculated according to:

$$\sigma_{\mathrm{x}} = \sigma_{\mathrm{x.st}} \pm \sqrt{\sum \left(\sigma_{\mathrm{x.dyn}} \right)^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\sum \left(\sigma_{y.dyn} \right)^2}$$

$$\sigma_z = \sigma_{z.st} \pm \sqrt{\sum \left(\sigma_{z.dyn} \right)^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\sum \left(\tau_{xy.dyn} \right)^2}$$

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\sum \left(\tau_{xz.dyn} \right)^2}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\sum \left(\tau_{yz.dyn} \right)^2}$$

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ = static stresses

$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ = dynamic stresses

Each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

4.3 Design conditions

4.3.1 All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this Chapter, and the load scenarios are covered by *Pt 11, Ch 4, 4.2 Structural analyses 4.2.2*.

4.3.2 **On-site operation design condition**

Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, or by simplified linear elastic analysis.

(a) Plastic deformation and buckling shall be considered.

(b) Analysis shall be based on characteristic load values as follows:

Permanent Loads	Expected Values
Functional Loads	Specified Values
Environmental Loads	Wave loads are to be calculated at a return period of 100 years.

(c) For the purpose of strength assessment the following material parameters apply:

(i) R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0,2 per cent proof stress applies.

R_m = specified minimum tensile strength at room temperature (N/mm^2).

NOTE

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in cargo containment systems.

(ii) The above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. Subject to special consideration by LR, account may be taken of the enhanced yield stress and tensile strength at low temperature.

(d) The equivalent stress σc (von Mises, Huber) shall be determined by:

$$\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x \sigma_y - \sigma_x \sigma_z - \sigma_y \sigma_z + 3\left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2 \right)}$$

where

σ_x = total normal stress in x-direction

σ_y = total normal stress in y-direction

σ_z = total normal stress in z-direction

τ_{xy} = total shear stress in x-y plane.

τ_{xz} = total shear stress in x-z plane

τ_{yz} = total shear stress in y-z plane.

(e) Allowable stresses for materials other than those covered by Chapter 6 shall be subject to approval by LR in each case.

Details of the proposals are to be submitted for consideration.

(f) Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

The stresses resulting from the 10 000 year return period wave loading are not to exceed yield, or a higher stress level, provided permanent deformation can be permitted.

4.3.3 **Fatigue design condition**

(a) The fatigue design condition is the design condition with respect to accumulated cyclic loading.

(b) The maximum allowable cumulative fatigue damage ratio C_W is to be less than or equal to 0,5, but is to be no greater than 0,33 for any parts of the supporting structure which are not accessible for inspection during the service life of the unit.

The fatigue damage shall be based on the design life of the containment system but not less than 25 years unless agreed otherwise by LR.

(c) The fatigue assessment of the cargo containment system is to be verified in accordance with the ShipRight Procedure for Ship Units.

The loading/unloading history is to be consistent with the intended operation of the ship unit. Plastic strain is to be accounted for in the low cycle region. Loading and unloading cycles are to include a complete pressure and thermal cycle.

(d) Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

The S-N curves shall be based on a 97,6 per cent probability of survival corresponding to the mean minus two standard deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable C_w values specified in (g), (h) and (i).

(e) Analysis shall be based on characteristic load values as follows:

Permanent Loads	Expected Values
Functional Loads	Specified values or specified history
Environmental Loads	Expected load history, but not less than 10^8 cycles

If simplified dynamic loading spectra are used for the estimation of the fatigue life, those shall be specially considered by LR.

(f) Where the size of the secondary barrier is reduced, as is provided for in *Pt 11, Ch 4, 2.2 Cargo containment safety principles 2.2.3*, fracture mechanics analyses of fatigue crack growth shall be carried out for the primary barrier to determine:

- Crack propagation paths in the structure.
- Crack growth rate.
- The time required for a crack to propagate to cause a leakage from the tank.
- The size and shape of through thickness cracks.
- The time required for detectable cracks to reach a critical state.

The fracture mechanics are in general based on crack growth data taken as a mean value plus two standard deviations of the test data.

(a) In analysing crack propagation the largest initial crack or equivalent defect not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable.

(b) For the crack propagation analysis under the condition specified in *Pt 11, Ch 4, 4.3 Design conditions 4.3.3*, the simplified load distribution and sequence over the RD, as specified in *Pt 11, Ch 4, 1.1 Definitions 1.1.9*, may be used, unless different project-specific requirements apply. Project-specific requirements are to be submitted for consideration. Such distributions may be obtained as indicated in *Figure 4.4.1 Simplified load distribution*. Load distribution and sequence for longer periods, such as in (h) and (i) below shall be approved by LR.

(c) The arrangements shall comply with (g), (h) and (l) below as applicable:

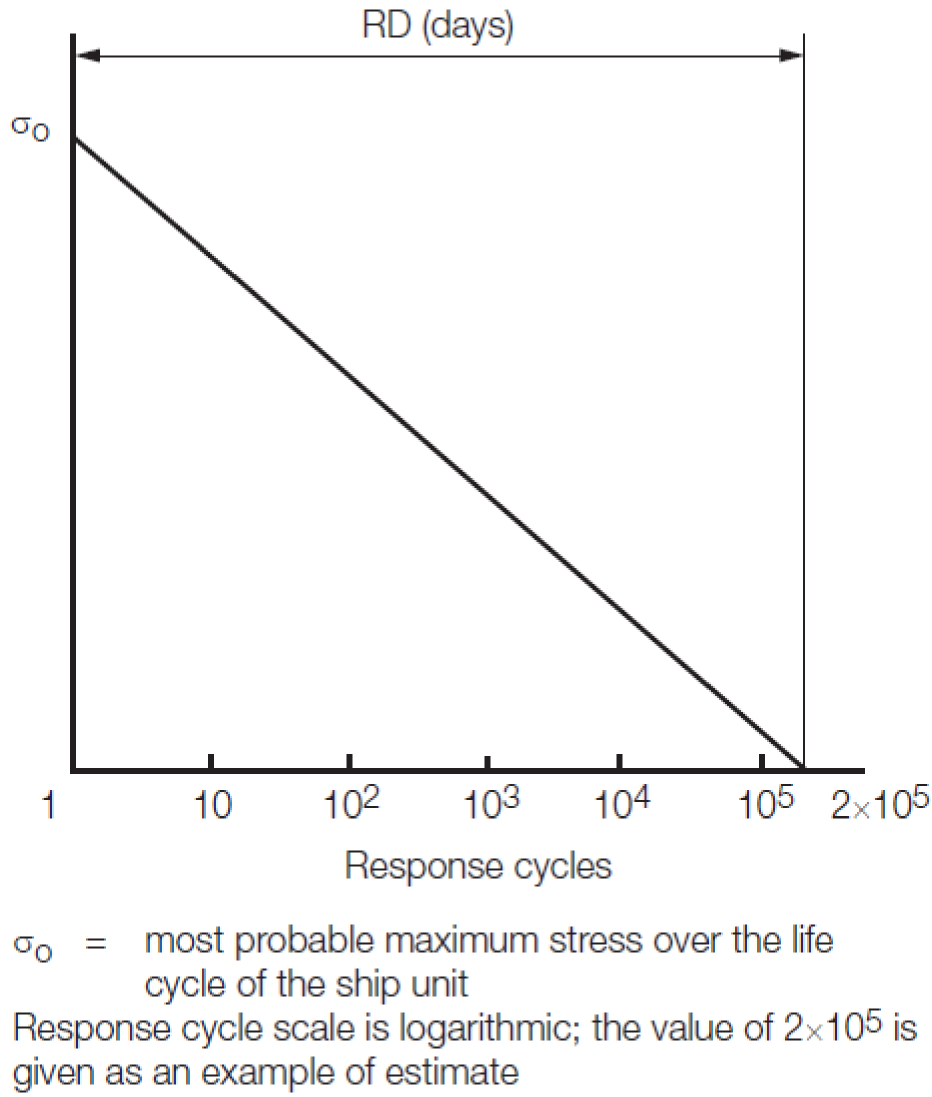


Figure 4.4.1 Simplified load distribution

(g) For failures that can be reliably detected by means of leakage detection;

- C_w shall be less than or equal to 0,5.
- The predicted remaining failure development time, from the point of detection of leakage until reaching a critical state, shall not be less than the RD, as specified in *Pt 11, Ch 4, 1.1 Definitions 1.1.1*, unless different project-specific requirements apply. Project-specific requirements are to be submitted for consideration.

(h) For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections;

- C_w shall be less than or equal to 0,5.
- Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three times the inspection interval.

(i) In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria should be applied as a minimum;

- C_w shall be less than or equal to 0,1.
- The predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three times the lifetime of the tank.

4.3.4 **Accident design condition**

The accident design condition is a design condition for accidental loads with extremely low probability of occurrence. Analysis shall be based on the characteristic values as follows:

Permanent Loads	Expected Values
Functional Loads	Specified values
Environmental Loads	Specified values
Accidental loads	Specified values or expected values

Loads mentioned in *Pt 11, Ch 4, 3.3 Functional loads 3.3.9* and *Pt 11, Ch 4, 3.5 Accidental loads* need not be combined with each other or with wave induced loads.

■ *Section 5*
Materials and construction

5.1 Materials

5.1.1 The specification and plans of the cargo containment system including the insulation are to be submitted for approval. The materials used are to be approved by LR, *see Pt 11, Ch 6 Materials of Construction and Quality Control* . For the plans to be submitted, *see Pt 11, Ch 1, 1.7 Information and plans*.

5.1.2 **Materials forming the structure of the ship unit**

(a) To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is cooler than –10°C. The following assumptions should be made in this calculation:

- (i) The primary barrier of all tanks shall be assumed to be at the cargo temperature.
- (ii) In addition to item (i), where a complete or partial secondary barrier is required it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only.
- (iii) The ambient temperatures for air and sea-water are to be based on those levels for which these temperatures have a probability of exceedance of 99,6 per cent. The ambient temperatures are to be rounded down to the nearest degree Celsius.
- (iv) Still air and sea water conditions shall be assumed, i.e. no adjustment for forced convection.
- (v) Degradation of the thermal insulation properties over the life of the ship unit due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations as defined in *Pt 11, Ch 4, 5.1 Materials 5.1.4*(g) and *Pt 11, Ch 4, 5.1 Materials 5.1.4*(h) shall be assumed.
- (vi) The cooling effect of the rising boil-off vapour from the leaked cargo should be taken into account where applicable.
- (vii) No credit shall be given for any means of heating, except as described in *Pt 11, Ch 4, 5.1 Materials 5.1.4*(e) and provided the heating arrangements are in compliance with *Pt 11, Ch 4, 5.1 Materials 5.1.4*(f).
- (viii) For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.
- (ix) Consideration should be given to scenarios in the lifecycle of the unit, other than on-site operation, where the cargo containment system may be used, tested or operated e.g. exposure to hotter or colder environmental temperatures.
- (x) The data set used for the ambient temperatures calculation should be sufficiently large to minimise uncertainties. Where limited data is available sufficient margins shall be included in the calculation to account for statistical uncertainties. It is the responsibility of the Owner to determine and propose the final ambient temperatures most suitable for a particular unit's operational requirements.
- (xi) These site specific ambient temperatures are supplementary to any other statutory requirements which may be applicable to the unit. As such, this Section is not intended to duplicate, alter, amend or supersede any requirements that may be imposed by the National Authority or Administrations.

When heat transmission studies are carried out, the heat balance method is acceptable to LR.

(b) The shell and deck plating of the ship unit and all stiffeners attached thereto shall be in accordance with the requirements of *Pt 10 SHIP UNITS* and this Part. If the calculated temperature of the material in the design condition is below –5°C due to the influence of the cargo temperature and ambient sea and air temperatures, the material shall be in accordance with *Table*

6.1.5 Plates and sections for hull structures required by (b) and (c). The ambient sea and air temperatures are to be determined as defined in (a)(iii).

(c) The materials of all other hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of cargo temperature and ambient sea and air temperatures, and that do not form the secondary barrier, shall also be in accordance with *Table 6.1.5 Plates and sections for hull structures required by (b) and (c)*. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members. The ambient sea and air temperatures are to be determined as defined in (a)(iii).

(d) The hull material forming the secondary barrier shall be in accordance with *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)*. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)* shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

(e) Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in *Table 6.1.5 Plates and sections for hull structures required by (b) and (c)*. In the calculations required in (a), credit for such heating may be taken in accordance with the following:

(i) for any transverse hull structure;

(ii) for longitudinal hull structure referred to in (b) and (c) where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of +5°C for air and 0°C for sea-water with no credit taken in the calculations for heating; and

(iii) as an alternative to (ii), for longitudinal bulkhead between cargo tanks, credit may be taken for heating provided the material remains suitable for a minimum design temperature of –30°C, or a temperature 30°C lower than that determined by *Pt 11, Ch 4, 5.1 Materials 5.1.2* with the heating considered, whichever is less. In this case, the longitudinal strength of the ship unit shall comply with SOLAS Regulation *Regulation 3-1 - Structural, mechanical and electrical requirements for ships* for both when those bulkhead(s) are considered effective and not.

(f) The means of heating referred to in *Pt 11, Ch 4, 5.1 Materials 5.1.2* shall comply with the following requirements:

(i) the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to not less than 100 per cent of the theoretical heat requirement;

(ii) the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with (e)(i) shall be supplied from the essential source of electrical power; and

(iii) the design and construction of the heating system shall be included in the approval of the containment system by LR.

Details of the proposed heating system are to be submitted.

5.1.3 **Materials of primary and secondary barriers**

(a) Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with *Table 6.1.1 Plates, pipes (seamless and welded, see Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for cargo design temperatures not lower than 0°C*, *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)* or *Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (see Notes 3 and 4)*.

(b) Materials, either non-metallic or metallic but not covered by *Table 6.1.1 Plates, pipes (seamless and welded, see Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for cargo design temperatures not lower than 0°C*, *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)* and *Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (see Notes 3 and 4)*, used in the primary and secondary barriers may be approved by LR considering the design loads that they may be subjected to, their properties and their intended use.

(c) Where non-metallic materials, including composites, are used for or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

- compatibility with the cargoes;
- solubility in cargo;
- absorption of cargo;

- ageing;
- density;
- mechanical properties;
- thermal expansion and contraction;
- abrasion;
- cohesion;
- resistance to vibrations;
- resistance to fire and flame spread;
- resistance to fatigue failure and crack propagation;
- influence of water;
- resistance to cargo pressure.

(d) The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum cargo design temperature, but not lower than –196°C.

(e) Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes shall also be tested as described above.

(i) Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in Appendix 1, 1,5.

(f) Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier.

5.1.4 **Thermal insulation and other materials used in cargo containment systems**

(a) Load-bearing thermal insulation and other materials used in cargo containment systems shall be suitable for the design loads.

(b) Thermal insulation and other materials used in cargo containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

- compatibility with the cargoes;
- solubility in the cargo;
- absorption of the cargo;
- shrinkage;
- ageing;
- closed cell content;
- density;
- mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction;
- abrasion;
- cohesion;
- thermal conductivity;
- resistance to vibrations;
- resistance to fire and flame spread;
- resistance to fatigue failure and crack propagation.

(c) In addition to the requirements given in (b), fatigue and crack propagation properties for insulation in membrane systems are also to be submitted. Insulation materials are to be approved by LR. Where applicable, these requirements also apply to any adhesive, sealers, vapour barriers, coatings or similar products used in the insulation system, any material used to give strength to the insulation system, components used to hold the insulation in place and any non-metallic membrane materials. Such products are to be compatible with the insulation.

(d) The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum cargo design temperature, but not lower than –196°C.

(e) Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with a recognised Standard acceptable to LR or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

(f) Thermal insulation that does not meet recognised Standards acceptable to LR for fire resistance may be used in hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal.

(g) Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

(h) Where powder or granulated thermal insulation is used, measures shall be taken to reduce compaction in service, for example due to vibrations, and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.

(i) Particular attention is to be paid to the cleaning of the steelwork prior to the application of the insulation. Where insulation is to be foamed or sprayed *in situ*, the minimum steelwork temperature at the time of application is to be indicated in the specification in addition to environmental conditions.

5.2 Construction processes

5.2.1 A construction, testing and inspection (CTI) plan for the installation of the containment system is to be submitted for approval. This plan is to list the following sequentially for each stage of installation, testing and inspection:

(a) The method to be used.

(b) The acceptance criteria.

(c) The form of record to be made.

(d) The involvement of the shipyard, containment system designer where relevant, and LR Surveyor.

The testing and inspection should be commensurate with assumptions made in the design of the containment system, *see Pt 11, Ch 4, 4.3 Design conditions 4.3.3* (f). Further detailed documents, which may be cross-referenced by the CTI plan, are to be submitted for approval as applicable.

5.2.2 A detailed quality assurance/quality control (QA/QC) programme shall be applied to ensure the continued conformity of materials in the containment system during installation and service. The quality assurance/quality control programme shall include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. The proposed procedure is to be submitted to LR for consideration. All materials in the containment system are also to be considered and included in the procedure. *See also* Appendix 1, 1.5.

5.2.3 **Weld joint design**

(a) All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds are also to be designed with full penetration.

Except for the dome-to-shell connections, T-butt welds will not be accepted in the shell.

(b) Welding joint details for Type C independent tanks, and for the liquid-tight primary barriers of Type B independent tanks primarily constructed of curved surfaces, shall be as follows:

   (i) All longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure.

   (ii) The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to LR. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

See also Pt 5, Ch 10, 14 Construction of the Rules for Ships.

(c) Where applicable, all the construction processes and testing, except that specified in *Pt 11, Ch 4, 5.2 Construction processes 5.2.5* shall be done in accordance with the applicable provisions of *Pt 11, Ch 6 Materials of Construction and Quality Control* .

5.2.4 **Design for gluing and other joining processes**

The design of the joint to be glued (or joined by some other process except welding) shall take account of the strength characteristics of the joining process.

5.2.5 **Testing during construction**

(a) All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks*, as applicable for the tank type.

(b) All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in (a).

(c) Requirements with respect to inspection of secondary barriers shall be decided by LR in each case, taking into account the accessibility of the barrier. *See also Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2*.

(d) The Administration may require that, for ship units fitted with novel Type B independent tanks or tanks designed according to *Pt 11, Ch 4, 8 Cargo containment systems of novel configuration*, at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation may be required for Type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

(e) The overall performance of the cargo containment system shall be verified for compliance with the design parameters during entry into service in accordance with the survey procedure. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained and be available to the Administration.

(f) The overall performance of the cargo containment system is to be verified for compliance with the design parameters during initial acceptance cargo trials. The initial trials are to be witnessed by LR's Surveyors, and are to demonstrate that the system is capable of being inerted, cooled, loaded and discharged in a satisfactory manner, and that all safety devices function correctly.

The temperature at which these tests are carried out is to be at or near the minimum cargo temperature. Where a refrigeration plant is fitted, its operation is to be demonstrated to the Surveyors. Records of the plant performance taken during entry into service at minimum temperature are to be submitted. Logs of plant performance are to be maintained for examination by the Surveyors when requested.

(g) Heating arrangements, if fitted in accordance with *Pt 11, Ch 4, 5.1 Materials 5.1.2* (e) and (f) *Pt 11, Ch 4, 5.1 Materials 5.1.2*, shall be tested for required heat output and heat distribution.

(h) The cargo containment system shall be inspected for cold spots during or immediately following entry into service. Inspection of the integrity of thermal insulation surfaces that can not be visually checked shall be carried out in accordance with recognised Standards.

(i) Repair Procedures shall define imperfection and defects and their allowable limits, identification of failure type and subsequent repair processes.

Repairs shall be of a quality standard as defined in *Pt 11, Ch 4, 5.2 Construction processes*.

Records of the performance of the repaired components and equipment, essential to verify the design parameters, shall be maintained and be available.

■ *Section 6* Tank types

6.1 Type A independent tanks

6.1.1 **Design basis**

(a) Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures. Type A independent tanks are to be designed in accordance with *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.3* and *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.4*. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_o shall be less than 0,07 MPa.

(b) If the cargo temperature at atmospheric pressure is below –10°C, a complete secondary barrier is required as defined in *Pt 11, Ch 4, 2.3 Secondary barriers in relation to tank types*. The secondary barrier shall be designed in accordance with *Pt 11, Ch 4, 2.4 Design of secondary barriers*.

6.1.2 **Structural analysis**

(a) A structural analysis shall be performed taking into account the internal pressure as indicated in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*, and the interaction loads with the supporting and keying system as well as a reasonable part of the hull of the ship unit.

(b) For parts such as supporting structures not otherwise covered by the requirements of this Part, stresses shall be determined by direct calculations, taking into account the loads referred to in *Pt 11, Ch 4, 3.2 Permanent loads* to *Pt 11, Ch 4, 3.5 Accidental loads* as far as applicable, and the deflection of the ship unit in way of supporting structures.

(c) The tanks with supports shall be designed for the accidental loads specified in *Pt 11, Ch 4, 3.5 Accidental loads*. These loads need not be combined with each other or with environmental loads.

6.1.3 **Symbols:**

b = width of plating supported, in metres

f = $1,1 - \frac{s}{2500S}$ but need not exceed 1,0

f_s = 2,7 for nickel steels and carbon manganese steels

= 3,9 for austenitic steels and aluminium alloys

h = vertical distance, from the middle of the effective span of stiffener or transverse to the top of the tank, in metres

l = effective span or girder or web, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point* of the Rules for Ships

l_e = effective length of stiffening member, in metres, *see Pt 3, Ch 3, 3.3 Determination of span point* of the Rules for Ships

l_t, l_s, l_b, l_c are effective spans measured according to Fig. *Figure 4.6.1 Measurement of spans*

ρ = maximum density of the cargo, in kg/m^3, at the cargo design temperature

k = higher tensile steel factor, *see Pt 3, Ch 2, 1.2 Steel* of the Rules for Ships

t_p = thickness, in mm, of the attached load bearing plating. Where this varies over the effective width of plating, the mean thickness is to be used

P_{eq} = the internal pressure head, in bar, as derived from *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* (a) and measured at a point on the plate one third of the depth of the plate above its lower edge

s = spacing of bulkhead stiffeners, in mm

S = spacing of primary members, in metres

S_w and s_1 are as defined in *Figure 10.5.1 Bracket toe construction* in *Pt 3, Ch 10, 5.2 Arrangements at intersections of continuous secondary and primary members* of the Rules for Ships.

The remaining symbols are as defined in *Pt 4, Ch 1, 9.2 Watertight and deep tank bulkheads* of the Rules for Ships. The lateral and torsional stability of stiffeners should comply with the requirements of *Pt 4, Ch 9, 5.6 Stability of longitudinals* of the Rules for Ships.

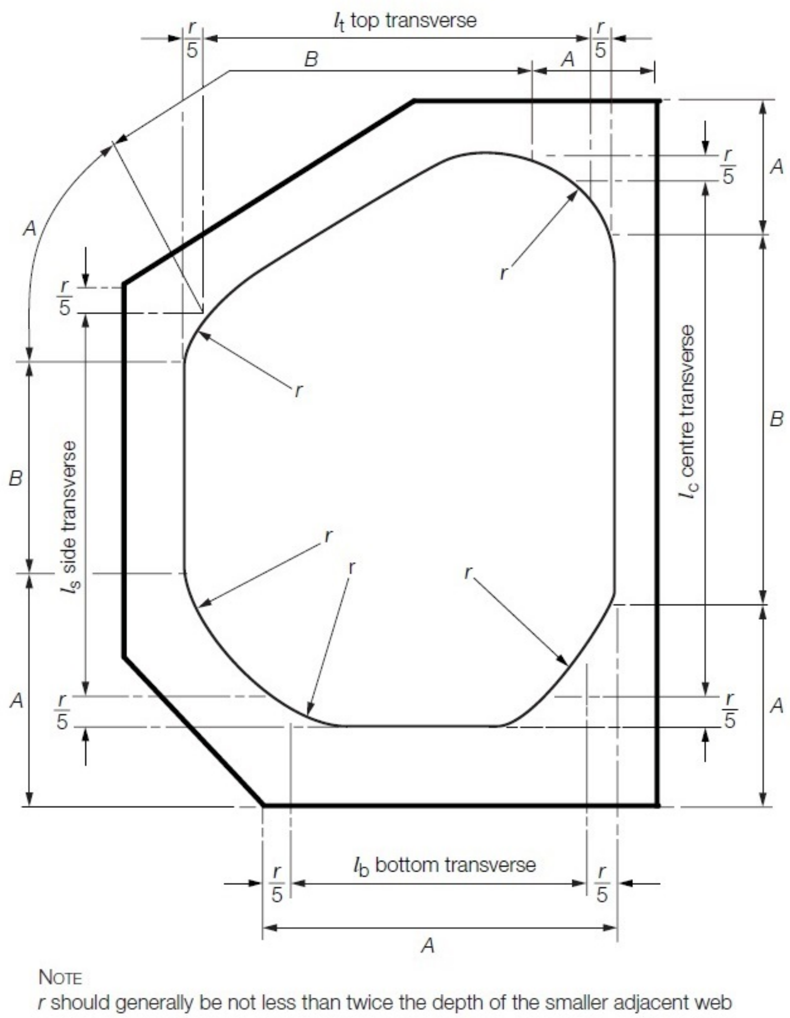


Figure 4.6.1 Measurement of spans

6.1.4 The scantlings of Type A independent tanks are to comply with the following:

(a) **Minimum thickness.**

No part of the cargo tank structure is to be less than 7,5 mm in thickness.

(b) **Boundary plating.**

The thickness of plating forming the boundaries of cargo tanks is to be not less than 7,5 mm, nor less than:

$t = 0,011 \mathrm{sf}\sqrt{\mathrm{P_{eq}k}}$ mm

NOTE

An additional corrosion allowance of 1 mm is to be added to the thickness derived if the cargo is of corrosive nature, *see also Pt 11, Ch 4, 2.1 Functional requirements 2.1.6* and *Pt 11, Ch 4, 2.1 Functional requirements 2.1.8*.

(c) **Rolled or built stiffeners.**

The section modulus of rolled or built stiffeners on plating forming tank boundaries is to be not less than:

$$Z = \frac{P_{eq} s k l_e^2}{f_s \gamma \left(\omega_1 + \omega_2 + 2 \right)} \text{ cm}^3$$

(d) **Transverses.**

The scantlings of transverse members are normally to be derived using direct calculation methods. The structural analysis is to take account of the internal pressure defined in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* (d) and also those resulting from structural test loading conditions. Proper account is also to be taken of structural model end constraints, shear and axial forces present and any interaction from the double bottom structure through the cargo tank supports.

As an initial estimate, the scantlings of the primary transverses may be taken as:

top transverse

$Z = 72 P_{eq}\, s\, l_t^2\, k$ cm3

topside transverse

$Z = 52 P_{eq}\, s\, l_t^2\, k$ cm3

side transverse

$Z = 56 P_{eq}\, s\, l_s^2\, k$ cm3

bottom transverse

$Z = 56 P_{eq}\, s\, l_b^2\, k$ cm3

centreline bulkhead transverse

$Z = 40 P_{eq}\, s\, l_c^2\, k$ cm3

The depth of the bottom transverse web is generally to be not less than l_b /4.

Web stiffening is to be in accordance with *Pt 4, Ch 9, 10.5 Primary member web plate stiffening* of the Rules for Ships with the application of the stiffening requirements as shown in *Figure 4.6.1 Measurement of spans*.

(e) **Tank end webs and girders.**

The section modulus of vertical webs and horizontal girders is to be not less than:

$Z = 85 P_{eq}\, b l^2\, k$ cm3.

(f) **Internal bulkheads (perforated).**

The thickness of plating is to be not less than 7,5 mm, but may require to be increased at the tank boundaries in regions of high local loading.

The section modulus of stiffeners, girders and webs is to be in accordance with *Pt 4, Ch 9, 8 Non-oiltight bulkheads* and*Pt 4, Ch 9, 9.8 Primary members supporting non-oiltight bulkheads* of the Rules for Ships.

(g) **Internal bulkheads (non-perforated).**

Where a bulkhead may be subjected to an internal pressure head, P_{eq}, resulting from loading on one side only, the scantlings of plating, stiffeners and primary members are to be determined from (b), (c) and (d).

Where no such loading condition is envisaged, the scantlings may be derived as follows:

The thickness of plating is to be not less than would be required for the tank boundary plating at the corresponding tank depth and stiffener spacing, reduced by 0,5 mm. The section modulus of stiffeners and transverses is to be derived from (c) or (d), respectively, but P_{eq} need not exceed:

$$\left(\frac{t_p - 1{,}0}{0{,}01265 \mathrm{sf} \sqrt{\mathrm{k}}} \right)^2 \text{ bar}$$

(h) **Tank crown structure.**

Where the minimum thickness of tank boundary plating (7,5 mm) has been adopted, the section modulus of associated stiffeners and transverses are to be derived as above, but P_{eq} is to be not less than that equivalent to the minimum thickness, that is:

$$P_{eq\ min} = \left(\frac{6{,}5}{0{,}01265 \mathrm{sf} \sqrt{\mathrm{k}}} \right)^2 \text{ bar}$$

The tank crown plating and stiffeners are also to be suitable for a head equivalent to the tank test air pressure where the tank is to be hydro-pneumatically tested.

(i) **Connection of stiffeners to primary supporting members.**

In assessing the arrangement at intersections of continuous secondary and primary members, the requirements of *Pt 3, Ch 10, 5.2 Arrangements at intersections of continuous secondary and primary members* are to be complied with using the requirements for 'other ship types'. The total load, P, in kN, is to be derived using the internal pressure head, P_{eq}, in bar as given by *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* (f) and the following formulae:

(a) In general:

$P = 100\ (S_w - 0{,}5s_1)s_1 P_{eq}$ kN

(b) For wash bulkheads:

$P = 120\ (S_w - 0{,}5s_1)s_1 P_{eq}$ kN.

6.1.5 **On-site operation design condition**

(a) For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of $R_m/2{,}66$ or $R_e/1{,}33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_e are defined in *Pt 11, Ch 4, 4.3 Design conditions 4.3.2* (c).

However, if detailed calculations are carried out for the primary members, the equivalent stress σ_C, as defined in *Pt 11, Ch 4, 4.3 Design conditions 4.3.2* (d), may be increased over that indicated above to a stress acceptable to LR. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

(b) Tank boundary scantlings shall meet at least the requirements of LR for deep tanks taking into account the internal pressure as indicated in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* and any corrosion allowance required by *Pt 11, Ch 4, 2.1 Functional requirements 2.1.6* and *Pt 11, Ch 4, 2.1 Functional requirements 2.1.7*.

(c) The cargo tank structure shall be reviewed against potential buckling.

6.1.6 **10 000 year return period design condition**

The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that there would be no gross failure of the cargo tanks, and no failure of the tank support system or pipe connections in this event.

6.1.7 **Accident design condition**

(a) The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in *Pt 11, Ch 4, 2.1 Functional requirements 2.1.5* (c) and *Pt 11, Ch 4, 3.5 Accidental loads*, as relevant.

(b) When subjected to the accidental loads specified in *Pt 11, Ch 4, 3.5 Accidental loads*, the stress shall comply with the acceptance criteria specified in *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.5*, modified as appropriate taking into account their lower probability of occurrence *see Figure 4.6.2 Hydro-pneumatic tank testing*.

6.1.8 **Testing**

All Type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic test.

This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydro-pneumatic test is performed, the conditions should simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.

The following equations calculate the head of water required to model the design pressure, P_{eq}, used in the scantling calculations of the tank structure. If a hydro-pneumatic test is utilised, the head of water h_{HP} is to be taken as:

$$h_{\mathrm{HP}} = \frac{10{,}2\left(P_{\mathrm{eq}} - P\right)}{RD} + y$$

where

h_{HP} = test head of water, in metres, measured from bottom of cargo tank

P_{eq} = design pressure, in bar, at location under consideration as derived from *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*

P = air test pressure, in bar

$RD = \rho/\rho_{freshwater}$

ρ = density of test fluid $\rho_{freshwater}$= 1000 kg/m^3 at 4°C

y = the vertical distance, in metres, from bottom of tank to the location under consideration, *see Figure 4.6.2 Hydro-pneumatic tank testing*

For a given head of water, h_{HP}, the load, in bar, at the location under consideration would be:

$$P_{\text{HP, LOAD}} = P + \frac{RD\left(h_{\text{HP}} - y\right)}{10,2}$$

Care is to be given that the ratio $\frac{P_{\text{HP, LOAD}}}{10,2P_{\text{eq}}} \leq 1,0$ at any point around the tank.

If a hydrostatic test is utilised, the head of water, h_{HS}, is to be taken as:

$$h_{\text{HS}} = \frac{10,2P_{\text{eq}}}{RD} - (h - y)$$

where

h_{HS} = test head of water, in metres, measured above top of cargo tank of depth h

h = height of tank as defined in *Figure 4.6.2 Hydro-pneumatic tank testing*)

For a given head of water, h_{HS}, the load, in bar, at the location under consideration would be:

$$P_{\text{HS, LOAD}} = \frac{RD\left[h_{\text{HS}} + (h - y)\right]}{10,2}$$

Care is to be given that the ratio $\frac{P_{\text{HP, LOAD}}}{10,2P_{\text{eq}} \leq 1,0}$ at any point around the tank.

The test pressure is to be not less than the MARVS.

The design pressure is not to be exceeded at any point, and the test should adequately load all areas of the tank. *See also Pt 3, Ch 1, 9.6 Definitions and details of tests*in the Rules for Ships. When testing takes place after installation of the tanks on board the ship unit, care is to be taken that the test head does not result in excessive local loading on the hull structure. For this purpose, when the cargo tanks are centrally divided with a non-perforated bulkhead, consideration will be given to testing the port and starboard sides of the tank independently.

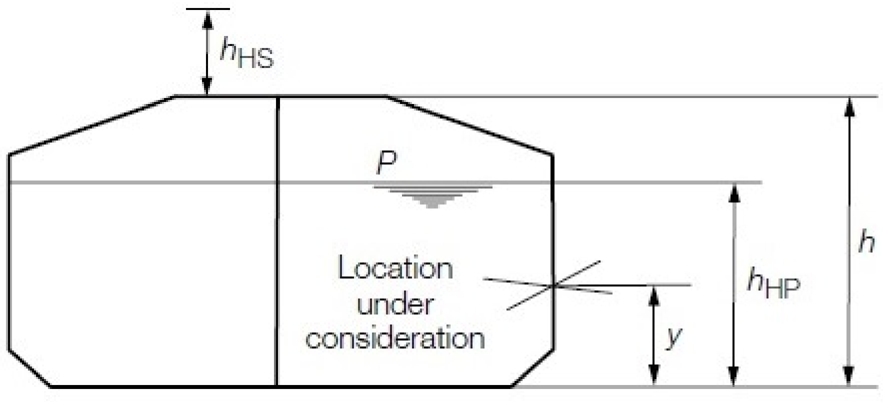


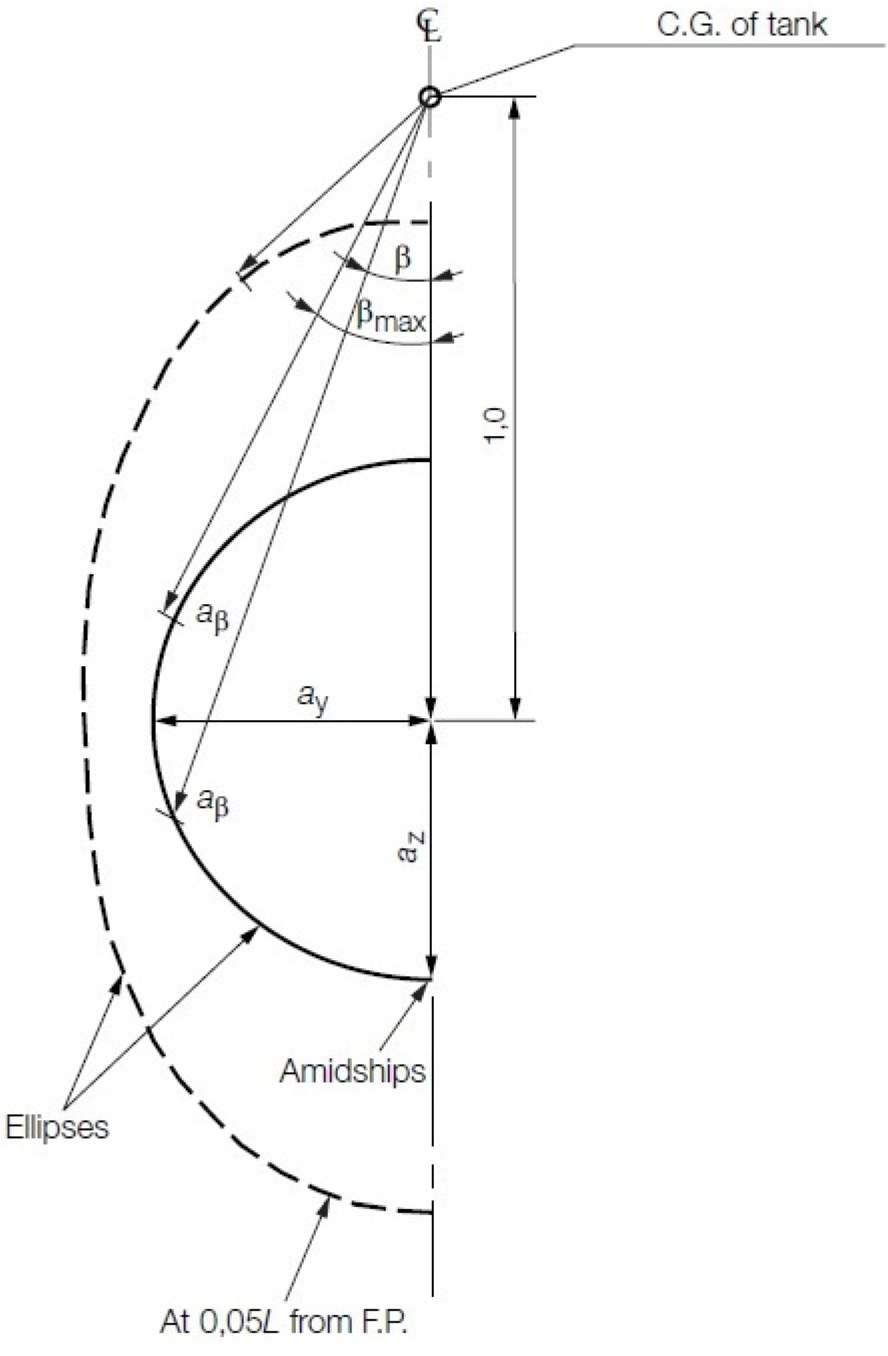
Figure 4.6.2 Hydro-pneumatic tank testing

6.2 Type B independent tanks

6.2.1 Design basis

(a) Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks) the design vapour pressure P_o shall be less than 0,07 MPa.

(b) If the cargo temperature at atmospheric pressure is below –10°C, a partial secondary barrier with a small leak protection system is required as defined in *Pt 11, Ch 4, 2.3 Secondary barriers in relation to tank types*. The small leak protection system shall be designed according to *Pt 11, Ch 4, 2.5 Partial secondary barriers and primary barrier small leak protection system*.



a_β = resulting acceleration (static and dynamic) in arbitrary direction β
a_y = transverse component of acceleration
a_z = vertical component of acceleration

Figure 4.6.3 Acceleration ellipse

6.2.2 **Structural analysis**

(a) The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

- plastic deformation;
- buckling;
- fatigue failure;
- crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, shall be carried out.

(b) A three-dimensional analysis shall be carried out to evaluate the stress levels, including interaction with the hull of the ship unit. The model for this analysis shall include the cargo tank with its supporting and keying system, as well as a reasonable part of the hull.

(c) A complete analysis of the particular accelerations and motions of the ship unit in irregular waves, and of the response of the ship unit and its cargo tanks to these forces and motions shall be performed unless the data is available from similar ship units.

(i) Type B independent tanks are to be subjected to a structural analysis by direct calculation procedures at a high confidence level. It is recommended that the assumptions made and the proposed calculation procedures be agreed with LR at an early stage. Where necessary, model or other tests may be required.

(ii) Generally, the scantlings of cargo tanks primarily constructed of plane surfaces are not to be less than required by *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.4* for Type A independent tanks. In assessing the cumulative effect of the fatigue load, account is to be taken of the quality control aspects such as misalignment, distortion, fit-up and weld shape. A 97,7 per cent survival probability S–N curve is to be adopted in association with a cumulative damage factor C_w value of 0,1 for primary members and 0,5 for secondary members. Alternative proposals will be specially considered.

6.2.3 **On-site operation design condition**

(a) **Plastic deformation**

Allowable stresses for Type B independent tanks are to be in accordance with *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.3* (i) and (ii) as applicable.

(i) For Type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses shall not exceed:

$\sigma_m \leq f$

$\sigma_L \leq 1{,}5f$

$\sigma_b \leq 1{,}5F$

$\sigma_L+\sigma_b \leq 1{,}5F$

$\sigma_m+\sigma_b \leq 1{,}5F$

$\sigma_m+\sigma_b+\sigma_g \leq 3{,}0F$

$\sigma_L+\sigma_b+\sigma_g \leq 3{,}0F$

where

σ_m = equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

σ_g = equivalent secondary stress

f = the lesser of (R_m/A) or (R_e/B)

F = the lesser of (R_m/C) or (R_e/D)

with R_m and R_e as defined in *Pt 11, Ch 4, 4.3 Design conditions 4.3.2* (c)(i). With regard to the stresses σ_m, σ_L and σ_b *see also* the definition of stress categories in *Pt 11, Ch 4, 7.1 Guidance Notes for Chapter 4 7.1.3*. The values *A, B, C* and *D* shall have at least the minimum values shown in *Table 4.6.1 Factors for determining allowable stress for Type B independent tanks*.

(ii) For Type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis will be specially considered:

(iii) The thickness of the skin plate and the size of the stiffener shall not be less than those required for Type A independent tanks.

Table 4.6.1 Factors for determining allowable stress for Type B independent tanks

	Nickel steel and carbon manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	2	1,6	1,5
C	3	3	3
D	1,5	1,5	1,5

(iv) **10 000 year return period design condition**

The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analysis are to be performed to show that there would be no gross failure of the cargo tanks, and no failure of the tank support system or pipe connections in this event.

(b) **Buckling**

Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognised standards. The method should adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

6.2.4 **Fatigue design condition**

(a) Fatigue and crack propagation assessment shall be performed in accordance with the provisions of *Pt 11, Ch 4, 4.3 Design conditions 4.3.3*.
(b) Fatigue analysis shall consider construction tolerances.
(c) Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

6.2.5 **Accident design condition**

(a) The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in *Pt 11, Ch 4, 3.3 Functional loads 3.3.9* and *Pt 11, Ch 4, 3.5 Accidental loads*, as relevant.
(b) When subjected to the accidental loads specified in *Pt 11, Ch 4, 3.5 Accidental loads*, the stress shall comply with the acceptance criteria specified in *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.3*, modified as appropriate, taking into account their lower probability of occurrence.

6.2.6 **Testing**

Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic test as follows:

- The test shall be performed as required in *Pt 11, Ch 4, 6.1 Type A independent tanks 6.1.8* for Type A independent tanks
- In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90 per cent of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75 per cent of the yield strength the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

6.2.7 **Marking**

Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

6.3 Type C independent tanks

6.3.1 **Design basis**

(a) The design basis for Type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.1* (b) is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.

(b) The design vapour pressure shall not be less than:

$P_o = 0,2 + AC(\rho_r)^{1,5}$ (MPa)

where:

$$A = 0,00185\left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with

σ_m = design primary membrane stress

$\Delta\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$)

= 55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel

= 25 N/mm^2 for aluminium alloy (5083-O)

C = a characteristic tank dimension to be taken as the greatest of the following: h, 0,75b or 0,45l

with

h = height of tank (dimension in ship unit's vertical direction) (m)

b = width of tank (dimension in ship unit's transverse direction) (m)

l = length of tank (dimension in ship unit's longitudinal direction) (m)

ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the cargo design temperature

When a specified design life of the tank is longer than 10^8 wave encounters $\Delta\sigma_A$ shall be modified to give equivalent crack propagation corresponding to the design life.

(c) Alternative means of calculating the design vapour pressure referred to in (b) will be accepted.

(d) The Administration may allocate a tank complying with the criteria of Type C, minimum design pressure as in (b), to a Type A or Type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

(e) Before construction of the pressure vessels is commenced, the following particulars, where applicable, and plans are to be submitted for approval:

- Nature of cargoes, together with maximum vapour pressures and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.
- Particulars of materials proposed for the construction of the vessels.
- Particulars of refrigeration equipment.
- General arrangement plan showing location of pressure vessels in the ship unit.
- Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.
- Plans of seatings, securing arrangements and deck sealing arrangements.
- Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.

6.3.2 **Shell thickness**

(a) The shell thickness shall be as follows:

(i) For pressure vessels, the thickness calculated according to (e) shall be considered as a minimum thickness after forming, without any negative tolerance.

(ii) For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

(iii) The welded joint efficiency factor to be used in the calculation according to (e) shall be 0,95 when the inspection and the non-destructive testing referred to in *Pt 11, Ch 6 Materials of Construction and Quality Control* are carried out. This value may be increased up to 1,0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels LR may accept partial non-destructive

examinations, but not less than those of *Pt 11, Ch 6 Materials of Construction and Quality Control* , depending on such factors as the material used, the cargo design temperature, the nil-ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0,85 should be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

(b) The design liquid pressure defined in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* shall be taken into account in the internal pressure calculations.

(c) The thickness of pressure parts subject to internal pressure is to be in accordance with *Pt 5, Ch 11 Other Pressure Vessels* of the *Rules and Regulations for the Classification of Ships, July 2016* except that:

(i) the welded joint efficiency factor, *J*, is to be as defined in (a)(iii) above;

(ii) the allowable stress is to be in accordance with *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3* (a);

(iii) the constant thickness increment (0,75 mm) included in the formulae in *Pt 5, Ch 11,2* of the*Rules and Regulations for the Classification of Ships, July 2016* may require to be increased in accordance with *Pt 11, Ch 4, 2.1 Functional requirements 2.1.6* or *Pt 11, Ch 4, 2.1 Functional requirements 2.1.7*.

(d) The design external pressure P_e , used for verifying the buckling of the pressure vessels, shall not be less than that given by:

$$P_e = P_1 + P_2 + P_3 + P_4 \text{ (MPa)}$$

where

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1 shall be specially considered, but shall not in general be taken as less than 0,025 MPa

P_2 = the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere $P_2 = 0$

P_3 = compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$.

(e) Scantlings based on internal pressure shall be calculated as follows:

The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*, including flanges, should be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with recognised Standards.

(f) Stress analysis in respect of static and dynamic loads shall be performed as follows:

(i) Pressure vessel scantlings shall be determined in accordance with (a) to (e) and *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3*.

(ii) Calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in *Pt 11, Ch 4, 3.2 Permanent loads* to *Pt 11, Ch 4, 3.5 Accidental loads* shall be used, as applicable. Stresses in way of the supporting structures shall be to a recognised standard acceptable to LR. In special cases a fatigue analysis may be required by LR.

(iii) If required by LR, secondary stresses and thermal stresses shall be specially considered.

6.3.3 **On-site operation design condition**

(a) **Plastic deformation**

For Type C independent tanks, the allowable stresses shall not exceed:

$\boldsymbol{\sigma_m} \le f$

$\boldsymbol{\sigma_L} \le 1{,}5f$

$\boldsymbol{\sigma_b} \le 1{,}5f$

$\sigma_L + \sigma_b \leq 1{,}5f$
$\sigma_m + \sigma_b \leq 1{,}5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3{,}0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3{,}0f$

where

σ_m = equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

σ_g = equivalent secondary stress

f = the lesser of (R_m/A) or (R_e/B)

with R_m and R_e as defined in *Pt 11, Ch 4, 4.3 Design conditions 4.3.2*. With regard to the stresses σ_m, σ_L, σ_b and σ_g *see also* the definition of stress categories in *Pt 11, Ch 4, 7.1 Guidance Notes for Chapter 4 7.1.3*. The values A and B shall have at least the minimum values shown in *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3*.

Table 4.6.2 Factors for determining allowable

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	1,5	1,5	1,5

(b) **10 000 year return period design condition**

The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analysis are to be performed to show that there would be no failure of, or leakage from, the pressure vessels, and no failure of the tank support system or pipe connections in this event.

(c) Buckling criteria shall be as follows:

The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

6.3.4 **Fatigue design condition**

For large Type C independent tanks where the cargo at atmospheric pressure is below –55°C, LR may require additional verification to check their compliance with *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.1*, regarding static and dynamic stress.

6.3.5 **Accident design condition**

(a) The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in *Pt 11, Ch 4, 2.1 Functional requirements 2.1.5* (c)(i) and *Pt 11, Ch 4, 3.5 Accidental loads*, as relevant.

(b) When subjected to the accidental loads specified in *Pt 11, Ch 4, 3.5 Accidental loads*, the stress shall comply with the acceptance criteria specified in *Pt 11, Ch 4, 6.3 Type C independent tanks 6.3.3*, modified as appropriate taking into account their lower probability of occurrence.

6.3.6 **Testing**

(a) Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1,5 P_o. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90 per cent of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed

0,75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

(b) The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

(c) The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

(d) Where necessary for cargo pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in (a) to (c) .

(e) When a hydro-pneumatic test is performed, the conditions are to simulate, so far as practicable, the actual loading of the tank and its supports.

(f) Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of (a) shall be fully complied with.

(g) After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.6*.

(h) Pneumatic testing of pressure vessels other than cargo tanks shall only be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

6.3.7 **Marking**

The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

6.4 Membrane tanks

6.4.1 **Design basis**

(a) The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

(b) A systematic approach, based on analysis and testing, shall be used to demonstrate that the system will provide its intended function in consideration of the identified in service events as specified in *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.2*.

(c) If the cargo temperature at atmospheric pressure is below –10°C a complete secondary barrier is required as defined in *Pt 11, Ch 4, 2.3 Secondary barriers in relation to tank types*. The secondary barrier shall be designed according to *Pt 11, Ch 4, 2.4 Design of secondary barriers*.

(d) The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value but less than 0,07 MPa.

(e) The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

(f) The thickness of the membranes is normally not to exceed 10 mm.

(g) The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with *Pt 11, Ch 9, 1.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks) 1.2.1*, shall be sufficient to allow for effective means of gas detection.

6.4.2 **Design considerations**

(a) Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

(i) Ultimate design events

- Tensile failure of membranes.
- Compressive collapse of thermal insulation.
- Thermal ageing.
- Loss of attachment between thermal insulation and hull structure.
- Loss of attachment of membranes to thermal insulation system.
- Structural integrity of internal structures and their supports.
- Failure of the supporting hull structure.

(ii) Fatigue design events

- Fatigue of membranes including joints and attachments to hull structure.

- Fatigue cracking of thermal insulation.
- Fatigue of internal structures and their supports.
- Fatigue cracking of inner hull leading to ballast water ingress.

(iii) Accident design events

- Accidental mechanical damage (such as dropped objects inside the tank while in service).
- Accidental over-pressurisation of thermal insulation spaces.
- Accidental vacuum in the tank.
- Water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

(b) The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.1* (b).

(c) **Loads, load combinations**

Particular consideration shall be paid to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, to hull vibration effects, or any combination of these events.

(d) **Structural analyses**

(i) Structural analyses and/or testing for the purpose of determining the strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in *Pt 11, Ch 4, 2.7 Associated structure and equipment* shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

(ii) Structural analyses of the hull shall take into account the internal pressure as indicated in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

(iii) The analyses referred to in *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.2* and *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.2* shall be based on the particular motions, accelerations and response of ship units and cargo containment systems.

(iv) The hull structure supporting the membrane tank is to be incorporated into the structural finite element model of the ship unit. The scantlings of the inner hull are to be not less than required by *Pt 10 SHIP UNITS*.

(v) Strength analysis is also to be carried out for structures inside the tank, i.e. pump towers, and its attachments. This should take account of hydrodynamic loads due to the sloshing motion of the cargo, inertia loading due to the accelerations of the vessel, and thermal effects due to loading and unloading of the tanks in accordance with the operational philosophy. The assessment is to consider stress levels, including shear stresses in the welds, buckling, fatigue (including fatigue due to thermal effects), and vibration.

6.4.3 **On-site operation design condition**

(a) The structural resistance of every critical component, sub-system, or assembly, shall be established, in accordance with *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.1* (b), for in-service conditions.

(b) The choice of strength acceptance criteria for the failure modes of the cargo containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.

(c) The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* and the specified appropriate requirements for sloshing load as defined in *Pt 11, Ch 4, 3.4 Environmental loads 3.4.4*.

(d) **10 000 year return period design condition**

The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Hull girder interaction loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that either the primary barrier or the secondary barrier should be expected to remain liquid tight and firmly fastened down in this event.

6.4.4 **Fatigue design condition**

(a) Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

(b) The fatigue calculations shall be carried out in accordance with *Pt 11, Ch 4, 4.3 Design conditions 4.3.3*, with relevant requirements depending on:

- The significance of the structural components with respect to structural integrity.
- Availability for inspection.

(c) For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w shall be less than or equal to 0,5.

(d) Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in *Pt 11, Ch 4, 4.3 Design conditions 4.3.3* (h).

(e) Structural elements not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in *Pt 11, Ch 4, 4.3 Design conditions 4.3.3* (i).

(f) Selected details of the containment system are to be investigated by fatigue analysis, which should take into account interactions with the vessel-supporting structure of the ship unit, including local, transverse and longitudinal hull girder effects, also pressure loading from the cargo and from ballast acting on the supporting structure. The number of cycles of full and partial loading and unloading are to be consistent with the operational philosophy of the unit. For investigation of the fatigue damage sustained by the secondary barrier following failure of the primary barrier, a simplified load distribution over the RD, as specified in *Pt 11, Ch 4, 1.1 Definitions 1.1.9* (a), may be used, unless different project-specific requirements apply, as described in *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2*. Project-specific requirements are to be submitted for consideration.

(g) The fatigue damage factor of both the containment system and internal structures such as pump towers is generally to be no greater than 0,5, but is to be no greater than 0,1 for any structural detail which is not accessible for survey during the service life of the vessel and whose failure would cause the simultaneous breach of both the primary and secondary barrier, such as the attachment weld of the pump tower base support.

6.4.5 Accident design condition

(a) The containment system and the supporting hull structure shall be designed for the accidental loads specified in *Pt 11, Ch 4, 3.5 Accidental loads*. These loads need not be combined with each other or with environmental loads.

(b) Additional relevant accident scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks.

6.4.6 Design development testing

(a) The design development testing required in *Pt 11, Ch 4, 6.4 Membrane tanks 6.4.1* (b) should include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype scaled model of the complete cargo containment system.

Testing conditions considered in the analytical and physical model shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life.

Proposed acceptance criteria for periodic testing of secondary barriers required in *Pt 11, Ch 4, 2.4 Design of secondary barriers 2.4.2* is to be based on the results of testing carried out on the prototype scaled model.

(b) The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests.

The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

6.4.7 Testing

In ship units fitted with membrane cargo containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.

All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.

Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

6.5 Integral tanks

6.5.1 Design basis

Integral tanks that form a structural part of the hull and are affected by the loads that stress the adjacent hull structure shall comply with the following:

(a) The design vapour pressure P_o as defined in *Pt 11, Ch 4, 1.1 Definitions 1.1.2* shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, P_o may be increased to a higher value, but less than 0,07 MPa.
(b) Integral tanks may be used for products provided the boiling point of the cargo is not below –10°C. A lower temperature may be accepted by LR subject to special consideration, but in such cases a complete secondary barrier shall be provided.

6.5.2 **Structural analysis**

(a) **On-site operation design condition**

Integral tanks are to be designed and constructed in accordance with the requirements for cargo tanks in *Pt 10 SHIP UNITS*, using the actual cargo density and additional vapour pressure.

(b) **10 000 year return period design condition**

The effects of 10 000 year return period wave loading on the containment system are to be considered. This is to include:

- Hull girder loading.
- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that there would be no gross failure of the cargo tanks in this event.

6.5.3 **Accident design condition**

(a) The tanks and the tank supports shall be designed for the accidental loads specified in *Pt 11, Ch 4, 2.1 Functional requirements 2.1.5* (e) and *Pt 11, Ch 4, 3.5 Accidental loads*, as relevant.

6.5.4 **Testing**

All integral tanks shall be hydrostatically or hydro-pneumatically tested. The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

6.6 Semi-membrane tanks

6.6.1 **Design basis**

(a) Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure; the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.
(b) The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value but less than 0,07 MPa.
(c) For semi-membrane tanks the relevant requirements in this Section for independent tanks or for membrane tanks shall be applied as appropriate.
(d) A structural analysis and other analyses and calculations should be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*.
(e) In the case of semi-membrane tanks that comply in all respects with the requirements applicable to Type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

■ *Section 7* Guidance

7.1 Guidance Notes for Chapter 4

7.1.1 **Guidance to detailed calculation of internal pressure for static design purpose**

(a) This Section provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure given in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* (d).

P_{gd} is the associated maximum liquid pressure determined using site-specific accelerations.

P_{eq} is to be calculated as follows:

$P_{eq} = P_o + P_{gd}$ (MPa)

(b) The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship unit referred to in *Pt 11, Ch 4, 3.4 Environmental loads 3.4.2*. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations shall be calculated as follows:

$$P_{\mathrm{gd}} = \alpha_\beta Z_\beta \left(\frac{\rho}{1,02 \times 10^5}\right) \mathrm{MPa}$$

where

α_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β, (*see Figure 4.6.3 Acceleration ellipse*)

Note for large tanks an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations should be used

Z = largest liquid height (in metres) above the point where the pressure is to be determined measured from the tank shell in the β direction (*see Figure 4.7.1 Determination of internal pressure heads*) Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_{\mathrm{d}} = V_{\mathrm{t}}\left(\frac{100 - FL}{FL}\right)$$

where

V_t = tank volume without any domes

FL = filling limit according to *Pt 11, Ch 15 Filling Limits for Cargo Tanks*

ρ = maximum cargo density (kg/m^3) at the cargo design temperature

The direction that gives the maximum value of P_{gd} shall be considered. Where acceleration components in three directions need to be considered, the ellipsoid shown in *Figure 4.7.3 Acceleration ellipsoids* shall be used instead of the ellipse in *Figure 4.6.3 Acceleration ellipse*. The above formula applies only to full tanks.

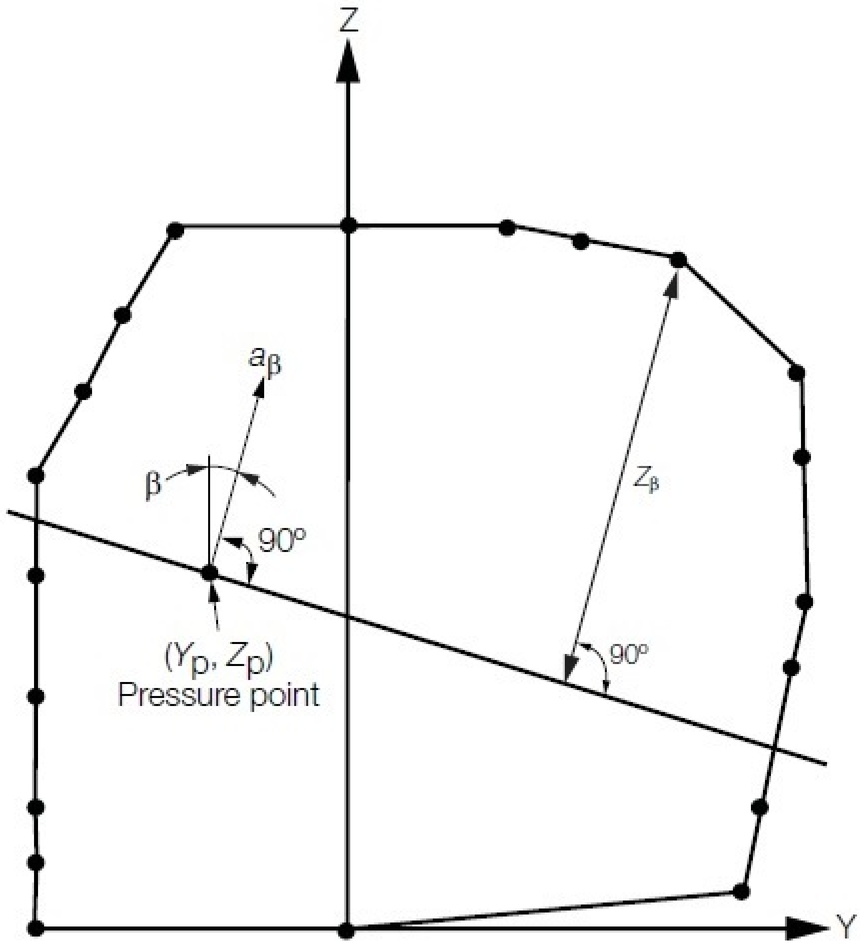


Figure 4.7.1 Determination of internal pressure heads

See also Figure 4.7.2 Determination of internal pressure heads.

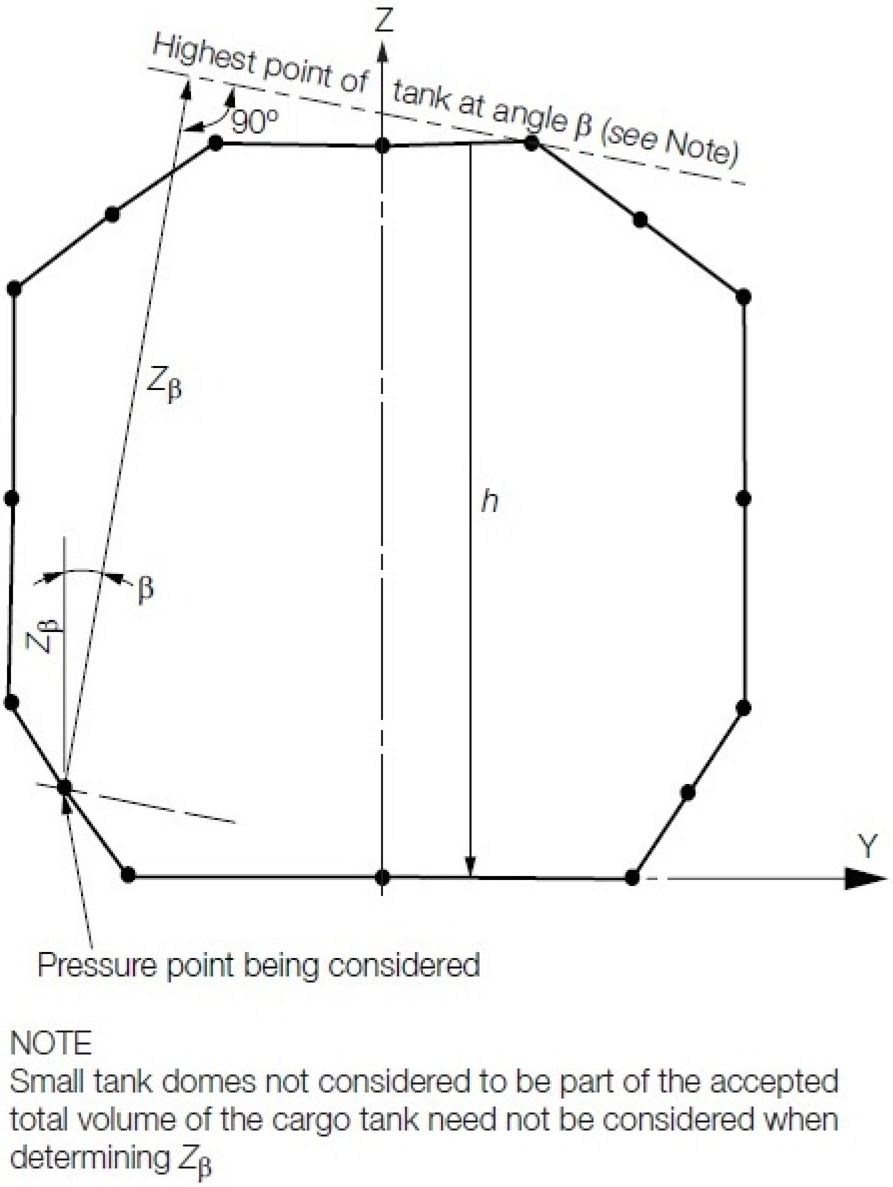


Figure 4.7.2 Determination of internal pressure heads

Accelerations in three dimensions are to be considered for ship units with independent spherical Type B tanks for which the ellipsoid as shown in *Figure 4.7.3 Acceleration ellipsoids* is to be used. Where loading conditions are proposed including one or more partially filled tanks, the internal liquid pressure to be used will be specially considered. *See also Pt 11, Ch 4, 3.4 Environmental loads 3.4.4*.

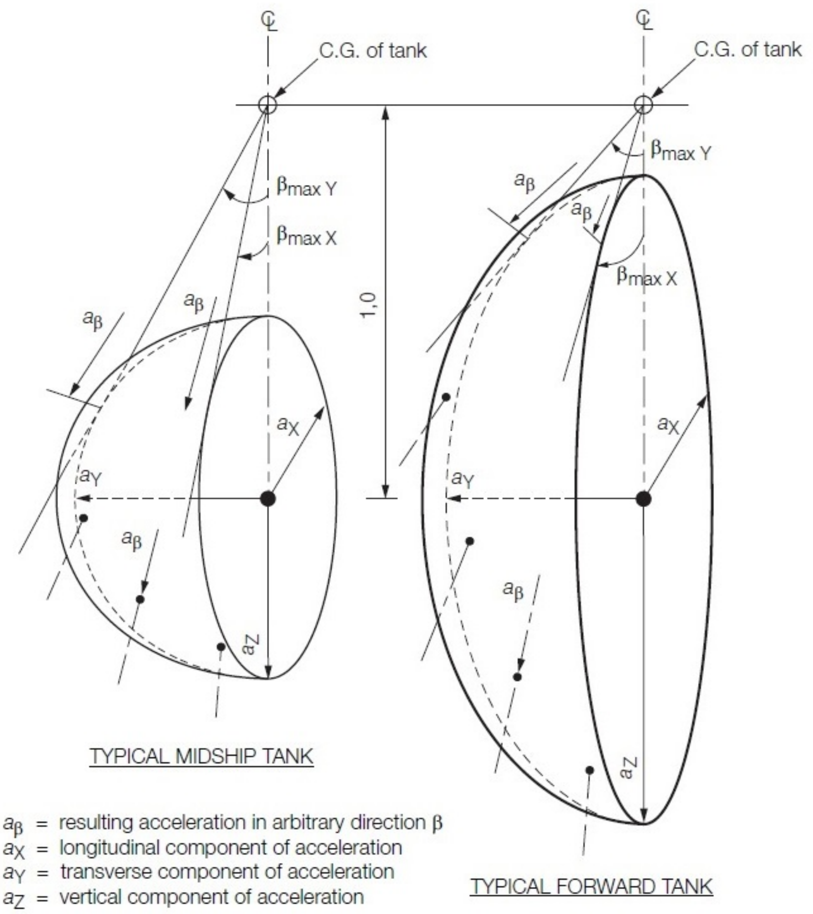


Figure 4.7.3 Acceleration ellipsoids

(c) Equivalent calculation procedures may be applied.

7.1.2 **Guidance formulae for acceleration components**

(a) The following formulae are given as guidance for the determination of the maximum value of internal liquid pressure head P_{gd}, (*see Pt 11, Ch 4, 7.1 Guidance Notes for Chapter 4 7.1.1*, internal pressure).

In the transverse direction, as shown in *Pt 11, Ch 4, 6.2 Type B independent tanks 6.2.1*, the following apply:

$$a_\beta = \frac{\cos\beta . a_y{}^2 + a_z . a_y \left(\cos^2\beta . a_y{}^2 + \sin^2\beta . a_z{}^2 - \sin^2\beta\right)^{0,5}}{\left(\cos^2\beta . a_y{}^2 + \sin^2\beta . a_z{}^2\right)}$$

The range of angle β is:

0 to β_{max}, with β_{max} = arc tan $\dfrac{a_y}{\left(1 - a_z{}^2\right)^{0,5}}$

For the longitudinal direction, β_{max} and a_β are to be determined with a_x substituted for a_y.

7.1.3 **Stress categories**

(a) For the purpose of stress evaluation, stress categories are defined in this Section.

(b) **Normal stress** is the component of stress normal to the plane of reference.

(c) **Membrane stress** is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

(d) **Bending stress** is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

(e) **Shear stress** is the component of the stress acting in the plane of reference.

(f) **Primary stress** is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.

(g) **Primary general membrane stress** is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

(h) **Primary local membrane stress** arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local if:

$S_1 \leq 0{,}5\sqrt{Rt}$ and
$S_2 \geq 2{,}5\sqrt{Rt}$

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds $1{,}1f$

S_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded

R = mean radius of the vessel

t = wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded

f = allowable primary general membrane stress.

(i) **Secondary stress** is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

■ *Section 8*
Cargo containment systems of novel configuration

8.1 Design for novel concepts

8.1.1 Cargo containment systems that are of a novel configuration that cannot be designed using sections *Pt 11, Ch 4, 6.1 Type A independent tanks* to *Pt 11, Ch 4, 6.6 Semi-membrane tanks* shall be designed using this section and Parts *Pt 11, Ch 4, 2 Cargo containment* and *Pt 11, Ch 4, 3 Design Loads Pt 11, Ch 4, 4 Structural Integrity* and *Pt 11, Ch 4, 5 Materials and construction* of this chapter, as applicable.

8.1.2 The procedure and relevant design parameters will be specially considered.

■ *Section 1* General

1.1 Applicability

1.1.1 The requirements of this Chapter apply to products and process piping, including vapour piping, gas fuel piping and vent lines of safety valves or similar piping. Auxiliary piping systems not containing cargo are exempt from the general requirements of this Chapter.

1.1.2 The requirements for Type C independent tanks provided in *Pt 11, Ch 4 Cargo Containment* may also apply to process pressure vessels. If so required, the term 'pressure vessels' as used in *Pt 11, Ch 4 Cargo Containment*, covers both Type C independent tanks and process pressure vessels.

1.1.3 Process pressure vessels include but are not limited to; surge vessels, heat exchangers and accumulators that store or treat liquid or vapour cargo.

1.1.4 Recognised standards for cryogenic process equipment are given in Part 3, Appendix A, 1.2.27.

1.2 System requirements

1.2.1 The cargo handling and cargo control systems shall be designed taking into account the following:

- Prevention of an abnormal condition escalating to a release of liquid or vapour cargo;
- The safe collection and disposal of cargo fluids released;
- Prevention of the formation of flammable mixtures;
- Prevention of ignition of flammable liquids or gases and vapours released;
- Limiting the exposure of personnel to fire and other hazards.

1.2.2 **Arrangements – General**

(a) Any piping system that may contain cargo liquid or vapour shall:

- be segregated from other piping systems, except where interconnections are required for cargo related operations such as purging, gas freeing or inerting. The requirements of *Pt 11, Ch 9, 1.4 Inerting 1.4.4* shall be taken into account with regard to preventing back flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections;
- except as provided in *Pt 11, Ch 16 Use of Cargo as Fuel*, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo machinery space;
- be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkway or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams;

- be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements in accordance with *Pt 11, Ch 3, 1.8 Tandem and side-by-side loading and unloading arrangements*, emergency cargo jettisoning piping systems in accordance with *Pt 11, Ch 5, 1.3 Arrangements for cargo piping outside the cargo area 1.3.1*, turret compartment systems in accordance with *Pt 11, Ch 5, 1.3 Arrangements for cargo piping outside the cargo area 1.3.3* and except in accordance with *Pt 11, Ch 16 Use of Cargo as Fuel*; and
- be located inboard of the transverse tank location requirements of *Pt 11, Ch 2, 1.4 Location of cargo tanks 1.4.1* except for emergency cargo jettisoning piping systems.

(b) Suitable means shall be provided to relieve the pressure and remove liquid cargo from discharging headers; likewise, any piping between the outermost discharge valves and loading arms or cargo hoses or any other location prior to the outermost valve that may be subject to pressurisation during discharging operations.

(c) Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area. (*See also Pt 11, Ch 13, 1.6 Gas detection 1.6.2* (f)).

(d) Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the flare system which is to be designed in accordance with API 521 *Guide for Pressure-relieving and Depressuring Systems: Petroleum petrochemical and natural gas industries-Pressure relieving and depressuring systems*. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.

1.3 Arrangements for cargo piping outside the cargo area

1.3.1 Emergency cargo jettisoning

(a) If fitted, an emergency cargo jettisoning piping system shall comply with *Pt 11, Ch 5, 1.2 System requirements 1.2.2* as appropriate and may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.

1.3.2 Bow and stern loading arrangements

(a) Subject to the requirements of *Pt 11, Ch 3, 1.8 Tandem and side-by-side loading and unloading arrangements*, this Section and *Pt 11, Ch 5, 4.3 Installation requirements for cargo piping outside the cargo area 4.3.1*, cargo piping may be arranged to permit bow or stern loading and unloading.

   (i) Arrangements shall be made to allow such piping to be purged and gas freed after use. When not in use the spool pieces shall be removed and the pipe ends blank flanged. The vent pipes connected with the purge shall be located in the cargo area.

1.3.3 Turret compartment transfer systems

(a) For the transfer of liquid or vapour cargo through an internal turret arrangement located, outside the cargo area, the piping serving this purpose shall comply with *Pt 11, Ch 5, 1.2 System requirements 1.2.2* as applicable, *Pt 11, Ch 5, 4.3 Installation requirements for cargo piping outside the cargo area 4.3.2* and the following;

   (i) Piping shall be located above the weather deck except for the connection to the turret.
   (ii) Portable arrangements shall not be permitted.
   (iii) Arrangements shall be made to allow such piping to be purged and gas freed after use. When not in use the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank flanged. The vent pipes connected with the purge shall be located in the cargo area.

1.4 Gas fuel piping systems

1.4.1 Gas fuel piping in machinery spaces shall comply with all applicable Sections of this Chapter in addition to the requirements of *Pt 11, Ch 16 Use of Cargo as Fuel*.

Section 2
Design aspects

2.1 Design pressure

2.1.1 The design pressure P_o, used to determine minimum scantlings of piping and piping system components, shall be not less than the maximum gauge pressure to which the system may be subjected in service. The minimum design pressure used shall not be less than 1 MPa except for; open ended lines or pressure relief valve discharge lines where it shall be not less than the lower of 0,5 MPa, or 10 times the relief valve set pressure.

2.1.2 The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:

(a) for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid: the saturated vapour pressure at a design temperature of 45°C. Higher or lower values may be used (*see Pt 11, Ch 4, 3.3 Functional loads 3.3.2*); or
(b) for systems or components that may be separated from their relief valves and which contain only vapour at all times: the superheated vapour pressure at 45°C. Higher or lower values may be used, *see Pt 11, Ch 4, 3.3 Functional loads 3.3.2*, assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or
(c) the MARVS of the cargo tanks and cargo processing systems; or
(d) the pressure setting of the associated pump or compressor discharge relief valve; or
(e) the maximum total discharge or loading head of the cargo piping system considering all possible pumping arrangements or the relief valve setting on a pipeline system.

2.1.3 Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this pressure.

2.1.4 The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

2.2 Cargo system valve requirements

2.2.1 Every cargo tank and piping system shall be fitted with manually-operated valves for isolation purposes as specified in this Section.

In addition, remotely operated valves shall also be fitted, as appropriate, as part of the emergency shut-down (ESD) system. The purpose of this ESD system is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress.

The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework.

The equipment to be shut down on ESD activation includes; manifold valves during loading or discharge, any pump or compressor etc transferring cargo internally or externally (e.g. to a shuttle tanker) plus cargo tank valves if the MARVS exceeds 0,07 MPa.

2.2.2 **Cargo tank connections**

(a) All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shut-off valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation; they may also be capable of remote operation.

For cargo tanks with a MARVS exceeding 0,07 MPa, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of *Pt 11, Ch 18, 4.2 ESD valve requirements* and provides full closure of the line.

2.2.3 **Cargo offloading connections**

(a) The offloading station is to provide a remotely controlled ESD valve prior to the hose connection to prevent liquid and vapour to or from the facility in the event of an incident. In the event that one or more transfer hoses are not used a manual and controlled by permit (or similar method) stop valve is to be provided prior to the hose connection.

In the event that the vapour return line is closed the ESD system is to be designed to stop all cargo pumping.

If the cargo tank MARVS exceeds 0,07 MPa an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the design of the ship unit.

2.2.4 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1,5 mm diameter circular hole.

2.2.5 All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation.

2.2.6 All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0,05 m^3 entrapped shall be provided with PRVs sized for a fire condition.

2.3 Cargo transfer arrangements

2.3.1 Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

2.3.2 The procedure for transfer of cargo by gas pressurisation shall preclude lifting of the relief valves during such transfer. Gas pressurisation may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as is permitted in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.8* and *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.9* the new set pressure is not to exceed P_h as is defined in *Pt 11, Ch 4, 3.3 Functional loads 3.3.2*.

2.3.3 **Vapour return connections**

(a) Connections for vapour return from the shuttle tanker to the ship unit shall be provided.

2.3.4 **Cargo tank vent piping systems**

(a) The pressure relief system shall be connected to a vent piping system designed to minimise the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.

2.3.5 **Cargo sampling connections**

(a) Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimise the release of cargo vapours.
(b) Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.
(c) On closed loop systems, the valves on the return pipe shall also comply with *Pt 11, Ch 5, 2.3 Cargo transfer arrangements 2.3.5*.
(d) The connection to the sample container shall comply with a recognised Standard and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.
(e) Sample connections used only for vapour samples may be fitted with a single valve in accordance with *Pt 11, Ch 5, 2.2 Cargo system valve requirements*, *Pt 11, Ch 5, 4.1 Piping fabrication and joining details* and *Pt 11, Ch 5, 6.2 Testing requirements*, and shall also be fitted with a closure plug or flange.
(f) Sampling operations shall be undertaken as in *Pt 11, Ch 18, 2 Storage and transfer*.

2.3.6 **Cargo filters**

(a) It is anticipated that liquefied gas facilities will remove contaminants before liquefaction. In the event that further filtration is anticipated, e.g. cool down during commissioning, the following shall be applied.

The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by foreign objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris, etc. entering the cargo system. Means shall be provided to indicate that filters are becoming blocked. Means shall be provided to isolate, depressurise and clean the filters safely.

■ *Section 3* Installation

3.1 Installation design requirements

3.1.1 Design for expansion and contraction

(a) Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.

3.1.2 Precautions against low temperature

(a) Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at cargo transfer connections and at pump seals, protection for the hull beneath shall be provided.

3.1.3 Protection of steelwork and personnel against uncontrolled cryogenic release

(a) Requirements are to be provided to minimize the risks associated with the uncontrolled release of low temperature liquids. Such a release could result in evaporation and dispersion of the product and, in cases, could cause brittle fracture of unprotected hull, deck and support structures. In locations where a release of low temperature liquid could occur, suitable mitigation methods are to be provided. The techniques selected need to consider; the inventory volume, maximum liquid pressure, minimum liquid temperature and the location of possible leakage.

(b) If drip trays and impoundment are used the material shall be selected to withstand exposure at the saturation temperature of the released liquid. The boundaries of the drip tray and impoundments are to be such to remain effective at the angles of inclination stated in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1* of the *Rules and Regulations for the Classification of Offshore Units*.

(c) The effect of drip trays and impoundments containing low temperature liquid is not to effect supporting or adjacent steelwork. The fitting of thermal breaks to drip tray supports and insulation between impoundments and supporting steelwork structure is to be considered.

(d) Where it is established that the liquid release may be substantial, the ability to drain drip trays and impoundments to be drained to an appropriate location or collection vessel is to be provided.

(e) Unless the material has been selected accordingly, a water distribution system shall be fitted in way of the hull under the discharge connections to provide a low-pressure water curtain for additional protection of the hull steel and the side structure. This system is in addition to the requirements of *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1*, and shall be operated when discharging is in progress.

(f) Personnel access ways, escape routes and refuge areas are to be protected against the possibility of uncontrolled release of low temperature liquids.

3.1.4 Bonding

(a) Where tanks or cargo piping and piping equipment are separated from the structure of the ship unit by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1 MΩ.

Section 4
Pipework

4.1 Piping fabrication and joining details

4.1.1 General

(a) The requirements of this Section apply to piping inside and outside the cargo tanks. Relaxation from these requirements may be accepted, in accordance with recognised Standards for piping inside cargo tanks and open-ended piping.

4.1.2 Direct connections

The following direct connection of pipe lengths, without flanges, may be considered:

(a) Butt welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than –10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back up on the first pass. For design pressures in excess of 1 MPa and design temperatures of –10°C or colder, backing rings shall be removed.
(b) Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognised Standards, shall only be used for instrument lines and open ended lines with an external diameter of 50 mm or less and design temperatures not colder than –55°C.
(c) Screwed couplings complying with recognised Standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

4.1.3 Flanged connections

(a) Flanges in flange connections shall be of the welded neck, slip-on or socket welded type.
(b) Flanges shall comply with recognised Standards for their type, manufacture and test. For all piping except open ended, the following restrictions apply:
    (i) For design temperatures colder than –55°C, only welded neck flanges shall be used.
    (ii) For design temperatures colder than –10°C, slipon flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.

4.1.4 Expansion joints

Where bellows and expansion joints are provided in accordance with *Pt 11, Ch 5, 3.1 Installation design requirements 3.1.1*, the following requirements apply:

(a) If necessary, bellows should be protected against icing.
(b) Slip joints shall not be used except within the cargo tanks.

4.1.5 Other connections

Piping connections shall be joined in accordance with *Pt 11, Ch 5, 4.1 Piping fabrication and joining details 4.1.2* to *Pt 11, Ch 5, 4.1 Piping fabrication and joining details 4.1.4*, but for other exceptional cases the Administration may consider alternative arrangements.

4.2 Welding, post-weld heat treatment and non-destructive testing

4.2.1 General

(a) Welding shall be carried out in accordance with *Pt 11, Ch 6 Materials of Construction and Quality Control*

4.2.2 Post-weld heat treatment

Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon manganese and low alloy steels. LR may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

4.2.3 Non-destructive testing

In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this paragraph, the following tests shall be required:

(a) 100 per cent radiographic or ultrasonic inspection of butt-welded joints for piping systems with design temperatures colder than –10°C, or with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm;

(b) When such butt-welded joints of piping sections are made by automatic welding procedures approved by LR, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10 per cent of each joint. If defects are revealed the extent of examination shall be increased to 100 per cent and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently; and

(c) For other butt-welded joints of pipes not covered by *Pt 11, Ch 5, 4.2 Welding, post-weld heat treatment and non-destructive testing 4.2.3* and *Pt 11, Ch 5, 4.2 Welding, post-weld heat treatment and non-destructive testing 4.2.3*, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10 per cent of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

4.3 Installation requirements for cargo piping outside the cargo area

4.3.1 Bow and stern loading arrangements

(a) The following provisions apply to cargo piping and related piping equipment located outside the cargo area:

- (i) Cargo piping and related piping equipment outside the cargo area shall have only welded connections. The piping outside the cargo area shall run on the weather decks and shall be at least 0,8 m inboard, except for cargo transfer connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location it shall also be capable of being separated, by means of a removable spool piece and blank flanges, when not in use.
- (ii) The piping is to be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the cargo transfer connections.

4.3.2 Turret compartment transfer systems

(a) The following provisions apply to liquid and vapour cargo piping where it is run outside the cargo area:

- (i) Cargo piping and related piping equipment outside the cargo area shall have only welded connections.
- (ii) The piping shall be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

4.3.3 Gas fuel piping

(a) Gas fuel piping, as far as practicable, shall have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3*, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be subjected to full radiographic or ultrasonic inspection.

■ *Section 5* Components

5.1 Piping system requirements

5.1.1 Piping scantlings

(a) Piping systems shall be designed in accordance with recognised Standards.

(b) The following criteria shall be used for determining pipe wall thickness.

The wall thickness of pipes shall not be less than:

$$T = \frac{t_o + b + c}{1 - \frac{a}{100}} \text{ (mm)}$$

where

t_o = theoretical thickness

$$t_0 = \frac{PD}{2Ke + P} \text{ (mm)}$$

with

P = design pressure (MPa) referred to in *Pt 11, Ch 5, 2.1 Design pressure*

D = outside diameter (mm)

K = allowable stress (N/mm^2) referred to in *Pt 11, Ch 5, 5.2 Stress aspects 5.2.1*

e = efficiency factor equal to 1,0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non destructive testing on welds is carried out in accordance with Recognised Standards. In other cases an efficiency factor of less than 1,0, in accordance with recognised Standards, may be required depending on the manufacturing process

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be:

$$b = \frac{Dt_0}{2,5r} \text{ (mm)}$$

with

r = mean radius of the bend (mm)

c = corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the expected life of the piping

a = negative manufacturing tolerance for thickness (per cent).

5.1.2 The minimum wall thickness shall be in accordance with recognised Standards.

5.1.3 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by *Pt 11, Ch 5, 5.1 Piping system requirements 5.1.1* (b) or, if this is impracticable or would cause excessive local stresses, these loads shall be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supporting structures, deflections of the ship unit, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

5.1.4 **Flanges, valves and fittings**

(a) Flanges, valves and other fittings shall comply with recognised Standards, taking into account the material selected and the design pressure defined in *Pt 11, Ch 5, 2 Design aspects*. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.
(b) For flanges not complying with a recognised Standard, the dimensions of flanges and related bolts shall be to the satisfaction of LR.
(c) All emergency shutdown valves shall be of the 'fire closed' type. (*See Pt 11, Ch 5, 6.2 Testing requirements 6.2.1* and *Pt 11, Ch 18, 4.2 ESD valve requirements*).
(d) The design and installation of expansion bellows shall be in accordance with recognised Standards and be fitted with means to prevent damage due to over-extension or compression.

5.1.5 **Ship unit cargo hoses**

(a) Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.
(b) Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.
(c) Each new type of cargo hose, complete with end fittings, shall be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has

been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature. Hoses used for prototype testing shall not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced shall be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure, but not more than two fifths of its bursting pressure. The hose shall be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 1 MPa.

5.2 Stress aspects

5.2.1 Allowable stress

(a) For pipes, the allowable stress to be considered in the formula for *t* in *Pt 11, Ch 5, 5.1 Piping system requirements 5.1.1* is the lower of the following values:

R_m/A or R_e/B

where

R_m = specified minimum tensile strength at room temperature (N/mm^2)

R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress strain curve does not show a defined yield stress, the 0,2 per cent proof stress applies.

The values of A and B shall have values of at least A = 2,7 and B = 1,8.

5.2.2 High pressure gas fuel outer pipes or ducting scantlings

(a) In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1,5 (i.e. R_m /1,5) when subjected to the design pressure specified in *Pt 11, Ch 5, 2.2 Cargo system valve requirements 2.2.1*. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

5.2.3 Stress analysis

(a) When the cargo design temperature is –110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hogging and sagging of the ship unit for each branch of the piping system shall be submitted to LR. For temperatures above –110°C, a stress analysis may be required by LR in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration should be given to thermal stresses even though calculations are not submitted. The analysis may be carried out according to a Code of Practice acceptable to LR.

■ *Section 6* Material selection and testing

6.1 Materials

6.1.1 Piping systems

(a) The choice and testing of materials used in piping systems shall comply with the requirements of *Pt 11, Ch 6 Materials of Construction and Quality Control* , taking into account the minimum cargo design temperature. However, some relaxation may be permitted in the quality of material of open ended vent piping providing the temperature of the cargo at the pressure relief valve setting is not colder than –55°C and provided no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi membrane tanks.
(b) Materials having a melting point below 925°C shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.

6.1.2 Cargo piping insulation system

(a) Cargo piping systems shall be provided with a thermal insulation system as required to minimise heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.

(b) Where applicable, due to location or environmental conditions, insulation materials should have suitable properties of resistance to fire and flame spread and should be adequately protected against penetration of water vapour and mechanical damage.

(c) Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt laden atmosphere, adequate measures to avoid this occurring should be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.

6.2 Testing requirements

6.2.1 Type testing of piping components

(a) **Valves**

(i) Reference is made to the SIGTTO publication *The Selection and Testing of Valves for LNG Applications*. Each type of piping component shall be subject to the following type tests:

Each type of piping component intended to be used at a working temperature below –55°C shall be subject to the following type tests:

(a) Each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of LR. During the testing satisfactory operation of the valve shall be verified.

(b) The flow or capacity shall be certified to a recognised Standard for each size and type of valve.

(c) Pressurised components shall be pressure tested to at least 1,5 times the rated pressure.

(d) For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard acceptable to the Administration. Reference is made to API Std 607 *Fire Test for Soft Seated Quarter Turn Valves.*

(b) **Expansion bellows**

(i) The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Recognised Organisation, on those installed within the cargo tanks:

- Elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.
- A pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.
- A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.
- A cyclic fatigue test (deformation of the ship unit) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2 000 000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, deformation loads from the ship unit are actually experienced.

6.2.2 System testing requirements

(a) The requirements of this Section apply to piping inside and outside the cargo tanks.

(b) After assembly, all cargo and process piping shall be subjected to a strength test with a suitable fluid. The test pressure is to at least 1,5 times the design pressure (1,25 times the design pressure where the test fluid is compressible) for liquid lines and 1,5 times the maximum system working pressure (1,25 times the maximum system working pressure where the test fluid is compressible) for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation onboard the ship unit. Joints welded onboard shall be tested to at least 1,5 times the design pressure.

(c) After assembly onboard, each cargo and process piping system shall be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

(d) In double wall gas fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

(e) All piping systems, including valves, fittings and associated equipment for handling cargo or vapours, shall be tested under normal operating conditions not later than at the first loading operation, in accordance with recognised Standards.

■ *Section 7* Cryogenic releases

7.1 Cryogenic liquefied gas spill control

7.1.1 General

(a) Cryogenic liquefied gases are liquids that are kept in their liquid state at very low temperatures.

(b) Cryogenic liquefied gas release can cause or contribute to the failure of safety critical structures and equipment due to the embrittlement of steel or control systems in contact with the release.

(c) This Section considers the brittle fracture of critical structures and equipment as well as the failure of control systems due to cooling to a critical temperature following a leak of a cryogenic liquefied gas.

7.1.2 Scope

(a) The requirements of this Section are additional to those of this Chapter and are applicable to offshore units which are intended for the processing and carriage of cryogenic liquefied gas(es) in bulk.

7.1.3 Application

(a) The following Rules are applicable to the cryogenic process equipment, associated cryogenic piping systems and pipework serving essential safety systems in way of or within the vicinity of the cryogenic process area on board an offshore unit.

(b) Requirements for fire safety are not included in these Rules; instead they are subject to the satisfactory requirements of the National Administration.

7.1.4 Documents and plans

(a) Plans, together with particulars as detailed in this Section, are to be submitted for approval. Any subsequent modifications are subject to approval before being put into operation.

(b) A description of the expected method of operation of the process plant and a diagram showing the process flow are to be submitted.

(c) Particulars of the proposals for isolating the offshore unit from the shore/subsea installation and/or vessels, where applicable, are to be submitted, including:

- Feedstock supply and product discharge, with details of the arrangements showing the location of shut-off valves and of the control and indicating stations.
- The process plant parameters and analysis of transient conditions under which emergency shut-down will be initiated and the time estimated to obtain a safe environment.
- The proposed emergency procedures for controlled shut-down of the process plant, i.e. depressurising, inerting, etc. and the arrangements for the continued operation of the essential services necessary to allow for such controlled shut-down under the emergency conditions.

(d) A risk assessment, or equivalent method acceptable to LR, is to be carried out for cryogenic liquefied gas spill.

(e) Risk assessment is to be carried out by representative specialists from the Owner, Builder and independent body/third party.

(f) A summary of the risk assessment is to be documented and submitted to LR for “for review only”.

(g) Depending on the likelihood and consequence of failures identified in the risk analysis, typical prevention and mitigation measures should be proposed or referred to.

(h) Each component of the cryogenic process equipment such as, and not limited to tanks, pumps, compressors, pipelines, valves and vessels must be considered as a potential source of cryogenic release. Special consideration shall be made for components which are not generally considered to be a source of cryogen release such as all welded pipelines, pressure vessels and associated welded instrumentation.

(i) During the risk assessment each identified accident/casualty scenario shall where necessary be graded with respects to severity of consequence and likelihood of occurrence. This grading shall provide a risk ranking that can be related to an appropriate risk matrix. The risk matrix shall distinguish risk into a series of groupings;

- unacceptable or intolerable;
- tolerable if ALARP; and
- acceptable, tolerable or negligible.

The risk matrix may be adapted from the IMO Guidelines on Formal Safety Assessment (FSA) – MSC/Circ.1023 MEPC/Cic.392 and the target individual risk levels for crew members given by the FSA for LNG-Carriers - MSC 72/16.

7.1.5 **Detection of cryogenic spill**

(a) A detection system shall be provided to give warning of any cold spot due to the leakage of LNG or natural gas.
(b) Detecting of cold spots may include but are not limited to:

- Gas detection.
- Metal temperature monitoring.
- Thermal imaging.
- Visual inspection.
- Video monitoring.
- Monitoring of process parameters.

(c) The equipment installed for cold spot detection is to be approved by LR.

7.1.6 **Cryogenic spill containment and suppression**

(a) Isolation valves, for inventory control purposes, must be located as close as practically possible to vessels or equipment.
(b) Inventory isolation valves that are located within a recognised fire zone shall be protected against fire and explosion effects.
(c) For inventory control under fire conditions consideration shall be given to automatic operation of valves where:

- manual operation of valves may involve danger to operators;
- require a rapid response;
- need unusual strength or dexterity.

(d) Where inventory isolation valves are automatically operated, they will need to be an emergency shut-down valves which are actuated by a process trip/alarm and/or actuated by gas or fire alarm.

7.1.7 **Limiting liquid gas spills and releases**

(a) Suitable arrangements are to be provided to reduce the chance of unintentional releases of liquid gas and mitigate the effects of such releases.
(b) Spray shields shall be fitted in way of all demountable joints, such as the terminal manifolds where leakage may occur at valves and pipe joints. Propriety shields or clamps, surrounding each demountable flange, fabricated from a material suitable for the pipework's contents, may be proposed.
(c) Where open drive pumps are installed, splash guards and drip trays around and below the pump shaft seal shall be provided. Guards and drip trays shall be constructed of a suitable material as per the requirements of *Pt 11, Ch 6, 1.4 Requirements for metallic materials*.
(d) Where the inventory of liquid gas necessitates, the use of impoundments shall be proposed. In process areas where there are numerous valves, fittings, pumps and flanges a common impoundment, covering the area of possible liquid release, may be required.
(e) The capacity of the drip trays/impoundment shall be based on an assessment of the largest credible containable spill. For guidance, if means are provided to automatically detect liquid releases, this capacity may be the contents of the pipework between isolating valves. For discharge facilities this capacity may be outboard section of one transfer arm, or one cargo hose, plus the volume of liquid between one of the unit's manifold valves and the highest point in the crossover.

7.2 Blowdown/depressurisation

7.2.1 Blowdown is defined as

(a) The depressurisation of a system, part of a system and its equipment to allow the safe disposal of both vapour and liquid discharged from blowdown valves. Depressurisation is used to mitigate the consequences of a pipeline or vessel leak by reducing the leakage rate and/or inventory within the pipe or vessel prior to a potential failure.

7.2.2 A depressurisation and blowdown system shall be provided for depressurising the high pressure liquid and gas pumps, vessels and pipework. The recommendations and guidelines given in standards such as ISO 23251 due to it being applicable to liquefied natural gas (LNG) and oil and gas production facilities shall be used for establishing a basis of design.

7.2.3 Where a liquid depressurisation system is provided, adequate provision shall be made in the design and installation for the effects of back pressure in the system and vapour flash-off when the pressures of liquids in the blowdown system are reduced.

7.2.4 Manual and automatic activation of the depressurisation system shall be provided.

7.2.5 Manual activation of the depressurisation system shall be possible from the process control station, local to the vessel or system being protected. Activation from other locations, as determined by the type, number, location and position of the process systems and equipment, shall also be possible. The designer of the system should recognise that a manual control may not be accessible during a fire.

7.2.6 Automatic activation shall be part of the emergency shutdown arrangements.

7.2.7 The maximum potential system release inventory due to depressurisation should be calculated for both individual systems and the maximum common-mode event. Consideration can be given to project specific philosophies such as staged blowdown. The disposal system is to be sized to deal with the maximum common-mode event inventory and resultant flash gas. To prevent exceeding the flare system capacity, the use of a liquid blowdown collection drum, knockout drum or liquid return to the storage tanks where possible, shall be proposed.

7.2.8 Substances which will react with each other are to be provided with separate systems.

7.3 Protection of steelwork against brittle fracture

7.3.1 Requirements are to be provided to minimize the risks associated with the uncontrolled release of low temperature liquids. In locations where a release of low temperature liquid could occur, suitable mitigation methods are to be provided. The techniques selected need to consider; the inventory volume, maximum liquid pressure, minimum liquid temperature and the direction of possible leakage.

7.3.2 Where drip trays and impoundment are used the material shall be selected to withstand exposure at the saturation temperature of the released liquid. The boundaries of the drip tray and impoundments are to be such to remain effective at the angles of inclination stated in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1*.

7.3.3 Drip trays and impoundments containing low temperature liquid are not to adversely affect supporting or adjacent steelwork. The fitting of thermal breaks to drip tray supports and insulation between impoundments and supporting steelwork structure is to be considered.

7.3.4 Where it is established that the liquid release may be substantial, the ability to drain drip trays and impoundments to be drained to an appropriate location or collection vessel is to be provided.

7.3.5 Unless the material has been selected accordingly, a water distribution system shall be fitted in way of the hull under the discharge connections to provide a low-pressure water curtain for additional protection of the hull steel and the side structure. This system is in addition to the requirements of *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* (d), and shall be operated when discharging is in progress.

7.3.6 Personnel access ways, escape routes and refuge areas are to be protected against the possibility of uncontrolled release of low temperature liquids.

■ *Section 8*
Liquefied gas transfer systems

8.1 General requirements

8.1.1 **Application**

(a) The Rules contained within this Chapter apply to liquefied gas transfer system(s) installed on board offshore units, for the purpose of transferring liquefied gas between an offshore unit and a commercially trading Liquefied gas tanker.
(b) The *Rules and Regulations for the Classification of Offshore Units* are applicable to liquefied gas floating production units and liquefied gas floating storage ship and barge type units. Unless a dedicated or novel offloading design is proposed, the gas carriers used for transferring liquefied gas will have been designed in accordance with the IGC Code, Classification Rules and

industry guidance. Thus the means provided for discharging liquid gas are to be in compliance with standard marine practices with regard to Class, layout, loadings and support. Consideration is to be given to guidance provided in the SIGTTO publication titled; Manifold Recommendations for Liquefied Gas Carriers.

(i) Where the method of offloading is of a novel design, such as a tandem over the bow arrangement, the design of the liquefied gas transfer system is to be shown to achieve the same level of safety and integrity as a standard marine system.
(ii) Where a traditional loading arm offloading arrangement is installed consideration shall be given to the effects of environmental factors such as unit motions and accelerations. Loading arm support columns are to be designed in accordance with the requirements of *Pt 3, Ch 7, 2.7 Lifting appliances*of these Rules.
(iii) Suitable facilities are to be installed to allow periodic maintenance such as the change out of offloading swivels, bearings and PERC overhaul whilst the unit remains on station.
(iv) Each type and design of offloading arrangement is to have the ability to be locked in a safe storage position in the event of extreme storms.

(c) Requirements additional to these Rules may be imposed by the National Authority with whom the offshore unit is registered and/or by the Administration within whose territorial jurisdiction the offshore unit is intended to operate.
(d) Requirements for fire safety are not included in these Rules; instead they are subject to the satisfactory requirements of the National Administration.

8.1.2 **Surveys**

(a) The survey of these items is to be arranged to coincide with hull and machinery surveys. *See* Periodical Survey Chapter and Section.

8.1.3 **Design and operating principles**

(a) Where the operation of the unit is to be at a specific location consideration will be given to the metocean data applicable to that area rather than the global ambient conditions stated in *Pt 6, Ch 2, 1.9 Ambient reference and operating conditions* of these Rules. Safety systems and essential auxiliary machinery are to operate at the angles of inclination given in *Pt 5, Ch 1, 2.1 Inclination of unit 2.1.1* of these Rules. Any proposal to deviate from these angles of inclination will be specially considered taking into account the type, size and service conditions of the unit.
(b) Unless agreed otherwise, the unit is to be capable of operation within specified operating conditions that include maximum sea states, wind conditions and those identified in the Rules for Offshore Units. Where the metocean data applicable to the area where the unit will be stationed provides lesser environmental conditions, consistent with the expected usage, these may be accepted. The following information is to be submitted where relevant to the offloading unit type and its design. Design environmental criteria applicable to each mode, including wind speed, wave height and period, or sea state/wave energy spectra (as appropriate), water depth, tide and surge, current speed, minimum air temperature, ice and snow loads. Consideration is to be given to the content of *Pt 3, Ch 10, 3.3 Metocean data* of these Rules.
(c) Liquefied gas transfer systems are to be designed and installed such that degradation or failure of any liquefied gas transfer systems will not render another essential system inoperable.
(d) Release of liquefied gas due to the failure, leak or rupture of the system must not lead to catastrophic failure of the hull structure.
(e) Liquefied gas transfer systems are to be capable of operating within the normal vibration modes and cyclic loads of the vessel.

8.2 Acceptance criteria

8.2.1 **General**

(a) These Rules have been developed to achieve a standard of design and construction quality that ensures an acceptable level of safety and assurance of integrity of the installation.
(b) Deviations from the Rules, using risk assessment as a method for justifying Class, must therefore demonstrate that such changes to the design and construction of an installation or its parts do not result in an unacceptable level of safety or integrity of the installation.

8.2.2 **Risk assessment and safety analysis**

(a) LR will require the Owner/Operator to develop risk acceptance criteria to be achieved by the design and maintained in service, to ensure the safety and integrity of the installation in line with the spirit and intent of Lloyd's Register's Rules.
(b) Risk acceptance criteria are subject to approval by LR.

(c) A safety and reliability analysis is to be carried out to demonstrate that the liquefied gas transfer system achieves a suitable level of safety and reliability. It is to be shown that this is at least equivalent to that associated with terminal practises (i.e., EN 1474, SIGTTO, OCIMF, OGP). The analysis is to be carried out in accordance with acceptable National or International standards such as; ISO/IEC Guide 73, ISO 16903, ISO/TC 16901 and OGP Draft 118683 as well as the spirit of the Revised IGC Code.

(d) The analysis is to include identification of the hazards associated with the operation and maintenance of the liquefied gas transfer system under all normal and reasonably foreseeable abnormal conditions, and, in the event of a single failure, the potential effects on the safety of the offshore unit and its occupants, its machinery and equipment, and the environment.

(e) When the analysis is to be carried out in accordance with land-based codes and standards, the acceptance criteria is to be verified as both appropriate and acceptable for the proposed transfer system when installed on the unit. The analysis is also considered the potential effects of any hazards identified as a result of abnormal conditions and is to include arrangements to mitigate any consequence.

(f) The analysis is to consider at least and not limited to the following hazards:

- low rate gas leakage, e.g. from joints, seals, etc.;
- high rate gas leakage, e.g. from pipe rupture;
- corrosion/erosion in gas piping, components and tanks;
- mechanical failure of liquefied gas transfer system, equipment or components;
- control/electrical failure of ESD system, ERS and electrical isolation in liquefied gas transfer system, equipment or components;
- manufacturing defects in equipment and machinery;
- human error in operation, maintenance, inspection and testing liquefied gas transfer, equipment and components;
- location of gas-containing tanks, piping, machinery, equipment and components;
- fire in areas or spaces containing tanks, piping, machinery, equipment and components;
- fire adjacent to areas or spaces containing liquefied gas transfer system, cargo tanks, piping, machinery, equipment and components;
- failure of lifting devices due to heavy loads, maximum sea states, wind conditions; and
- failure of quick coupling system.

(g) In order to facilitate the proper selection and installation of equipment to be used safely in areas where explosive gas atmospheres may occur, an area classification study, in accordance with *Pt 7, Ch 2, 2 Classification of hazardous areas* is to be carried out.

(h) To ensure that mechanical equipment located in hazardous areas does not represent a source of ignition, an ignition hazard assessment, in accordance with an acceptable National or International Standard such as EN 13463-1, is to be carried out. *See Pt 7, Ch 2, 5.1 General 5.1.2*.

(i) The assessment process for liquefied gas transfer systems will consider all aspects of the system including offshore unit to ship dynamic interaction and environmental effects.

(j) The transfer system is to be subject to both commissioning and acceptance trials to show compliance with both safety and operational performance criteria. The acceptance trials are to include operational testing and be witnessed by an attending Lloyd's Register Surveyor. All safety, operational and functional testing is to be demonstrated by the designer/Builder and Owner/Operator to the satisfaction of LR.

8.3 Documentation

8.3.1 Plans and particulars

(a) Plans, together with the relevant information as detailed in this Section, are to be submitted for consideration. Any subsequent modifications are subject to approval before being put into operation.

(b) Any alterations to basic design, construction, materials, manufacturing procedure, equipment, fittings or arrangements of the liquid gas transfer system are to be re-submitted for approval.

(c) A design statement of the liquefied gas transfer systems that details the capability and functionality under defined operating and emergency conditions. The design statement is to be agreed between the designers and Owners/Operators.

8.3.2 Lifting appliances.

(a) Plans and details of all lifting appliances as required by LR's *Code for Lifting Appliances in a Marine Environment* or other specified design code to be submitted.

8.3.3 Piping plans.

(a) Arrangements of loading/offloading system to be submitted for appraisal.

8.4 Materials

8.4.1 General

(a) The materials used in the construction are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and of Chapter 6 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as Rules for Ships for Liquefied Gases), as applicable. Materials for which provision is not made in those requirements may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.
(b) Materials of construction are to be suitable for the intended service, having regard to the substances, process and temperatures involved.
(c) Details of the materials proposed for all types of construction are to be submitted for approval.

8.5 Liquefied gas transfer system

8.5.1 General

(a) Operating requirement(s) associated with liquefied gas transfer are to meet the requirements of *Pt 11, Ch 18 Operating Requirements* of the Rules for Ships for Liquefied Gases.
(b) Transfer operations, accomplished by other means than transfer hoses and hard arms, will not be discounted but be given special consideration.
(c) All piping, valves and fittings are to be suitable for the design operating and environmental conditions.
(d) The piping is to comply with the requirements for manufacture, testing and certification of Class II piping systems.

8.5.2 Transfer hoses

(a) There are three types of cargo hoses suitable for liquefied gases transfer. These can be:

- Composite.
- Rubber.
- Stainless steel construction.

(b) Liquid and vapour hoses used for liquefied gas transfer should be compatible with the cargo and suitable for the cargo temperature. The design, construction and testing of such hoses are to be to a suitable national standard such as BS ISO 4089 or BS ISO 5842. For hoses carried on board ship refer to the Rules for Ships for Liquefied Gases.
(c) Each transfer hose should be permanently marked with the following information and be compliant with the requirements of EN 1474 and other applicable Regulations, such as IMO’s International Gas Code:

Hose serial number;
Internal diameter of the hose;
Overall weight of complete hose;
Date of manufacture;
Date of proof pressure testing;
Certifying authority stamp;
The maximum and minimum allowable working temperature range.

(d) The hose vendor should provide the following documents:

Hose certificate.
Hose quantity assurance manual.
Inspection, test and storage plan.
Operating manual.
Hose handling manual.

(e) Where required, hoses are to be supported in a suitably dimensioned cradle or saddle arrangement to ensure that the manufacturer’s bend radius criteria are met. These supports may be integral to the load restraint system thus preventing excessive axial and torsional loads on the cargo hose end fittings. The support’s design, fabrication and fixing arrangements should be such to avoid chafing of the hoses and ability to prevent damage to handrails and other unit fixtures and fittings in the event of an emergency separation.

(i) Due to the difference in electrical potential between the unit and loading ship, there is a risk of an incendive arc when the transfer arms are being connected or disconnected. Arrangements shall be made to avoid the risk of arcing from this source by the installation of an insulating flange in the transfer arm or hose.

(ii) Care shall be taken that the insulation flanges are not annulled by the use of electrically continuous hydraulic hoses.

(iii) The use of a unit-to-loading ship bonding cable is not only considered ineffective but can also be dangerous if it breaks in a flammable atmosphere, such as where the final stage ESD activation includes automatic separation.

(f) When selecting hose size and length, the manufacturer's recommendations should be followed to determine the maximum flow rate and other operating parameters. The maximum hose size will also be governed by the capabilities of the onboard lifting equipment and manifold construction.

(g) In determining the size and length of the hose(s) to be used, the following , in accordance with the requirements of the SIGTTO Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases, shall be considered:

- Minimum allowable bend radius of the hose;
- Horizontal distance between the unit and ship;
- Difference in fore and aft alignment (manifold offset);
- Distance between the manifold and the ship's side;
- Vertical and horizontal unit to ship movement;
- Any other special characteristics related to the unit;
- Relative change in freeboard between the unit and ship;
- Accessibility of flange connections which are to be minimised;
- Design flow rate for liquid and vapour hoses as established by the manufacturer;
- Hose handling requirements and limitations of the asset's equipment;
- For tandem offloading; the station-keeping accuracy of the loading ship or the maximum allowable elongation of the mooring hawser.

(h) The liquefied gas transfer equipment should be supported by suitable means to prevent excessive loads on manifold fittings, in accordance with OCIMF/SIGTTO manifold guidelines.

(i) Each hose is to be fitted with an emergency release coupling (ERC). The coupling is to be fitted with a valve, each side of the release point, which automatically closes before parting can occur. Manual activation of the coupling is also to be achievable.

(j) Operation of the ERC is to take place on activation of the emergency shutdown (ESD) system. The ERC is also to operate prior to the transfer hoses becoming over-extended. After activation, the resultant movement of the free end of the hose is to be such as to avoid the possibility of impact and sparking.

8.5.3 **Hard arm**

(a) Where hard arms are considered for use in liquefied gas transfer operations, the following criteria, in accordance with the requirements of the SIGTTO Ship to Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases, shall be taken into account:

- Accelerations;
- Permissible manifold loadings;
- Arm working envelope;
- Arm support arrangement;
- Arm stowage arrangement;
- The effect of vibration on the arm;
- Maintenance requirements;
- Size of the arm;
- Connectability;
- Vertical and horizontal unit to ship movement;
- Allowable flow velocity and pressure loss;
- Testing requirements.

(b) An electrical insulation of the hard arm extremity shall be supplied according to the requirements of EN 1474-1. This may take the form of an insulating flange installed in the lower end of the outboard arm or within the middle swivel of the triple swivel assembly. The purpose of the flange is to prevent stray currents from causing an arc at the loading ship's flange as the loading arm is connected or disconnected.

(c) The range of the operating envelope of the hard arm is to be determined by the perceived tidal variations and change of the freeboard between the offshore unit and receiving tanker whilst loading or discharge.

(d) The hard arm is to be provided with an emergency release system to provide a means to quickly uncouple the hard arms with minimum spillage in an emergency.

(e) The physical disconnection may be achieved by means of a powered emergency release coupler (PERC). The effect of PERC activation and the resultant behaviour of the free arms are to be demonstrated. Consideration needs to be given to mitigating the effects resulting from unit motions and that the free arms can be controlled without impacting each other. If a manual type of loading arm is proposed (counter-weighted pantograph type), the furthest extent of the area which the released end of loading arm could extend into would need to be established.

(f) The PERC valves shall close as quickly as reasonably possible with the valve closure time being sufficient to avoid unacceptable surge pressure in pipelines. Such valves should close in such a manner as to cut off the flows smoothly. An interlock shall be provided to ensure that both the upstream and downstream valves are closed prior to the emergency release coupling parting thus prevent or minimising loss of liquid.

(g) The powered emergency release coupler shall be equipped with a device or devices to prevent overpressure due to thermal expansion of trapped product between the valves which have been isolated due to the coupler's activation and resultant closure of the manifold valves due to activation of the ESD system.

8.6 Drain system

8.6.1 General

(a) Once the transfer operation has been completed and the loading ship 'topped off', all liquid lines, transfer hoses and hard arms will be in a liquid full condition. To alleviate the possibility of overpressure within these lines, there is to be a means to either drain these lines back to the storage tanks or provide a suitable drain tank arrangement.

(b) It is envisaged that the loading ship will not have the ability or storage capacity to allow the liquid transfer lines to be blown through. Thus the trapped inventory, from the storage tank pump outlet check valve to the manifold valve of the hard arm or transfer hose, will need to be returned to the floating production unit.

(c) Where novel arrangements are used, such as over the stern tandem boom arrangement, the amount of trapped inventory may be considerable. If due to location there is not the ability to drain the trapped liquid back to the storage tanks then a separate collection and storage tank system is to be provided.

(d) Depending on the liquid being transferred, were sufficient high pressure gas can be generated on board the unit this can be used to blow back the trapped liquid back to the storage tank. If there is the ability to remove non-condensable gases from the storage tanks gaseous nitrogen may be used in lieu of high pressure gas. After blowing through, the headers and discharge lines shall be able to remain connected to the storage tank vapour space thus allowing any remaining puddle of liquid to be boiled off.

(e) Where required, such as over the stern tandem systems were their location is remote from the storage tanks, a drain down arrangement, complete with local collection tank, may be required. This may take the form of a collection tank, having the ability, through either pressurisation or pump, to return the drained inventory back to the storage tanks. Thus any liquid remaining in the boom, manifold and header after discharge is complete would to drain back to the collection tank by gravity.

(f) When a separate collection tank is installed it would need to be provided with dedicated set of equipment and systems to service the tank. These are to include; high level and high pressure alarms, a means to empty the collection tank, a relief valve and vent arrangement suitable for the set pressure of the relief valves and vent gas temperature.

(g) Where low points are generated in liquid headers or manifold were liquid may be trapped these are to be fitted with a means to drain them in accordance with *Pt 11, Ch 5, 1.2 System requirements 1.2.2*.

■ Section 1
Materials of Construction and Quality Control

1.1 Definitions

1.1.1 Where reference is made in this Chapter to Grades A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.1.2 **A piece** is the rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

1.1.3 **A batch** is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in the recognised Standards.

1.1.4 **Accelerated Cooling (AcC)** is a process that aims to improve mechanical properties by controlled cooling with rates higher than air cooling, immediately after the final TMCP operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TMCP and AcC cannot be reproduced by subsequent normalising or other heat treatment.

1.1.5 **Controlled Rolling (CR)**, also known as **Normalising Rolling (NR)**, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

1.1.6 **Normalising (N)** refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

1.1.7 **Quenching and Tempering (QT)** is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.1.8 **Thermo-Mechanical Controlled Processing (TMCP)** is a procedure that involves strict control of both the steel temperature and the rolling reduction. Unlike CR, the properties conferred by TMCP cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TMCP may also be accepted subject to approval by the Administration. The same applies for the use of tempering after completion of the TMCP

1.2 Scope and general requirement

1.2.1 This Chapter gives the requirements for metallic and non-metallic materials used in the construction of the cargo system. This includes requirements for joining processes, production process, personnel qualification, NDT and inspection and testing including production testing. The requirements for rolled materials, forgings and castings are given in *Pt 11, Ch 6, 1.4 Requirements for metallic materials* and *Table 6.1.1 Plates, pipes (seamless and welded, see Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for cargo design temperatures not lower than 0°C*, *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)*, *Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (see Notes 3 and 4)*, *Table 6.1.4 Pipes (seamless and welded, see Note 1), forgings and castings (see Note 2) for cargo and process piping for cargo design temperatures below 0°C and down to –165°C (see Note 3), maximum thickness 25 mm* and *Table 6.1.5 Plates and sections for hull structures required by (b) and (c)*. The requirements for weldments are given in *Table 6.1.* and the guidance for non metallic materials is given in *Pt 11, Ch 21 Appendix 1 Non-Metallic Materials*. A quality assurance/quality control (QA/QC) program shall be implemented to ensure these requirements are complied with.

1.2.2 The manufacture, testing, inspection and documentation shall be in accordance with the requirements of this Chapter and the Rules for Materials. Testing and inspection to other recognised Standards will be subject to special agreement.

1.2.3 Where post-weld heat treatment is specified or required, the properties of the base materials, weld and heat affected zone shall be determined in the heat treated condition, in accordance with the requirements specified in this Chapter. Alternative arrangements for Charpy V-notch impact test temperature following post-weld heat treatment will be subject to special consideration.

1.3 General test requirements and specifications

1.3.1 All mechanical tests required by this Chapter shall be carried out in accordance with the Rules for Materials.

1.3.2 Acceptance tests for metallic materials shall include Charpy V-notch impact tests unless specified otherwise; the largest specimen possible for the material thickness should be machined. Requirements for testing specimens smaller than 5,0 mm in size shall be in accordance with recognised Standards.

1.3.3 The bend test may be omitted as a material acceptance test, but is required for weld tests.

1.4 Requirements for metallic materials

1.4.1 **General requirements for metallic materials**

(a) The requirements for materials of construction are shown in the Tables as follows:

Table 6.1.1 Plates, pipes (seamless and welded, see Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for cargo design temperatures not lower than 0°C:

Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2):

Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (see Notes 3 and 4):

Table 6.1.4 Pipes (seamless and welded, see Note 1), forgings and castings (see Note 2) for cargo and process piping for cargo design temperatures below 0°C and down to –165°C (see Note 3), maximum thickness 25 mm:

Table 6.1.5 Plates and sections for hull structures required by (b) and (c):

Table 6.1.1 Plates, pipes (seamless and welded, *see* Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for cargo design temperatures not lower than 0°C

Chemical composition and heat treatment		
• Carbon-manganese steel • Fully killed fine grain steel • Small additions of alloying elements by agreement with LR • Composition limits to be approved by LR • Normalised, quenched and tempered, *see* Note 4		
Tensile and toughness (impact) test requirements		
Sampling frequency		
• Plates	Each 'piece' to be tested	
• Sections and forgings	Each 'batch' to be tested	
Mechanical properties		
• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2, *see* Note 5	
Toughness (Charpy V-notch test)		
• Plates	Transverse test pieces. Minimum average value (*KV*) 27J	
• Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J	
• Test temperature	Thickness *t* (mm)	Test temperature (°C)
•	$t \leq 20$	0
	$20 < t \leq 40$, *see* Note 3	–20

NOTES

1. For seamless pipes and fittings, normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by LR.

2. Charpy V-notch impact tests are not required for pipes where the thickness is less than 15 mm.

3. This Table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by LR.

4. A controlled rolling (normalising rolling) procedure may be used as an alternative. In addition, TCMP steel may be used as an alternative in applications where post-weld heat treatment is not required.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by LR. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Table 6.1.2 Plates, sections and forgings (*see* Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)

Chemical composition and heat treatment

- Carbon-manganese steel
- Fully killed, aluminium treated fine grain steel
- Chemical composition (ladle analysis)

C	Mn	Si	S	P
0,16% max. *see* Note 3	0,70-1,60%	0,10-0,50%	0,025% max.	0,025% max.

Optional additions: Alloys and grain refining elements may be generally in accordance with the following:	

Ni	Cr	Mo	Cu	Nb	V
0,80% max.	0,25% max.	0,08% max.	0,35% max.	0,05% max.	0,10% max.

Al content total 0,020% min. (acid soluble 0,015% min.)	
• Normalised, or quenched and tempered, *see* Note 4	
Tensile and toughness (impact) test requirements	
Sampling frequency	
• Plates	Each 'piece' to be tested
• Sections and forgings	Each 'batch' to be tested
Mechanical properties	
• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2, *see* Note 5
Toughness (Charpy V-notch test)	
• Plates	Transverse test pieces. Minimum average energy value (*KV*) 27J
• Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J
• Test temperature	5°C below the cargo design temperature or –20°C, whichever is lower

NOTES

1. The Charpy V-notch and chemistry requirements for forgings may be specially considered by LR.
2. For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below cargo design temperature or –20°C, whichever is lower
$30 < t \leq 35$	15°C below cargo design temperature or –20°C, whichever is lower
$35 < t \leq 40$	20°C below cargo design temperature
$40 < t$	Temperature approved by LR

The impact energy value shall be in accordance with the Table for the applicable type of test specimen.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below cargo design temperature or –20°C, whichever is lower.

For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank shell thickness.

3. By special agreement with LR, the carbon content may be increased to 0,18% maximum provided the cargo design temperature is not lower than –40°C.

4. A controlled rolling (normalising rolling) procedure may be used as an alternative. In addition, TMCP steel may be used as an alternative in applications where post-weld heat treatment is not required.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by LR. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance

For materials exceeding 25 mm in thickness for which the test temperature is –60°C or lower, the application of specially treated steels or steels in accordance with *Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (see Notes 3 and 4)* may be necessary.

Table 6.1.3 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below –55°C and down to –165°C (see Note 2), maximum thickness 25 mm (*see* Notes 3 and 4)

Minimum cargo design temperature	Chemical composition, *see* Note 5, and heat treatment	Impact test temperature (°C)
–60	1,5% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Note 6	–65
–65	2,25% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Notes 6 and 7	–70
–90	3,5% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Notes 6 and 7	–95
–105	5% nickel steel – normalised or normalised and tempered or quenched and tempered, *see* Notes 6, 7 and 8	–110
–165	9% nickel steel – double normalised and tempered or quenched and tempered, *see* Note 6	–196
–165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated, *see* Note 9	–196
–165	Aluminium alloys; such as type 5083 annealed	Not required
–165	Austenitic Fe-Ni alloy (36% nickel) heat treatment as agreed	Not required
Tensile and toughness (impact) test requirements		
Sampling frequency		
• Plates	Each ‘piece’ to be tested	
• Sections and forgings	Each ‘batch’ to be tested	
Toughness (Charpy V-notch test)		
• Plates	Transverse test pieces. Minimum average energy value (KV) 27J	
• Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J	

NOTES

1. The impact test required for forgings used in critical applications shall be subject to special consideration by LR.

2. The requirements for cargo design temperatures below –165°C shall be specially agreed with LR.

3. For materials 1,5% Ni, 2,25% Ni, 3,5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below cargo design temperature
$30 < t \leq 35$	15°C below cargo design temperature
$35 < t \leq 40$	20°C below cargo design temperature

The energy value shall be in accordance with the Table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.

4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.

5. The chemical composition limits shall be in accordance with *Ch 3, 6 Ferritic steels for low temperature service* of the Rules for Materials.

6. TMCP nickel steels will be subject to acceptance by LR.

7. A lower minimum cargo design temperature for quenched and tempered steels may be specially agreed with LR.

8. A specially heat treated 5% nickel steel, for example, triple heat treated 5% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.

9. The impact test may be omitted subject to agreement with LR.

Table 6.1.4 Pipes (seamless and welded, *see* Note 1), forgings and castings (*see* Note 2) for cargo and process piping for cargo design temperatures below 0°C and down to –165°C (see Note 3), maximum thickness 25 mm

Minimum cargo design temperature	Chemical composition, *see* Note 5, and heat treatment	Impact test	
		Test temp. (°C)	Minimum average energy (KV)
–55	Carbon-manganese steel. Fully killed fine grain. Normalised or as agreed, *see* Note 6	*See* Note 4	27
–65	2.25% nickel steel. Normalised, normalised and tempered or quenched and tempered, *see* Note 6	–70	34
–90	3.5% nickel steel. Normalised, normalised and tempered or quenched and tempered, *see* Note 6	–95	34
–165	9% nickel steel, *see* Note 7. Double normalised and tempered or quenched and tempered	–196	41
–165	Austenitic steels, such as types 304. 304L, 316, 316L, 321 and 347. Solution treated, *see* Note 8	–196	41
–165	Aluminium alloys, such as type 5083 annealed		Not required
Tensile and toughness (impact) test requirements			
Sampling frequency			
• Each ‘batch’ to be tested.			
Toughness (Charpy V-notch test)			

• Impact test: longitudinal test pieces
NOTES 1. The use of longitudinally or spirally welded pipes shall be specially approved by LR. 2. The requirements for forgings and castings may be subject to special consideration by LR. 3. The requirements for design temperatures below –165°C shall be specially agreed with LR. 4. The test temperature shall be 5°C below the cargo design temperature or –20°C whichever is lower. 5. The composition limits shall be in accordance with *Ch 6, 4 Ferritic steel pressure pipes for low temperature service* of the Rules for Materials. 6. A lower cargo design temperature may be specially agreed with LR for quenched and tempered materials. 7. This chemical composition is not suitable for castings. 8. Impact tests may be omitted subject to agreement with LR.

Table 6.1.5 Plates and sections for hull structures required by *Pt 11, Ch 4, 5.1 Materials 5.1.2*

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above, *see* Note 1 –5 and above, *see* Note 2	To comply with *Pt 10, Ch 1, 3 Materials*							
down to –5	15	25	30	50	25	45	50	50
down to –10	x	20	25	50	20	40	50	50
down to –20	x	x	20	50	x	30	50	50
down to –30	x	x	x	40	x	20	40	50
Below –30	In accordance with *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)*, except that the thickness limitation given in *Table 6.1.2 Plates, sections and forgings (see Note 1) for cargo tanks, secondary barriers and process pressure vessels for cargo design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (see Note 2)* and in Note 2 of that Table does not apply							
NOTES 'x' means steel grade not to be used. 1. For the purpose of *Pt 11, Ch 4, 5.1 Materials 5.1.2* (c). 2. For the purpose of *Pt 11, Ch 4, 5.1 Materials 5.1.2* (b).								

1.4.2 The material grades for the construction of the hull structure are to comply with the requirements of *Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction* in *Pt 4, Ch 2 Materials* unless the minimum metal temperature is the result of heat conduction from the cargo, in which case hull materials shall be in accordance with *Pt 11, Ch 6, 1.4 Requirements for metallic materials 1.4.1*.

1.4.3 The sheerstrake is to be of Grade E/EH steel for ship units storing and offloading liquefied gases in bulk.

1.5 Welding of metallic materials and non-destructive testing

1.5.1 General

(a) This Section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may

be adapted for other materials. At the discretion of LR, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

1.5.2 **Welding consumables**

(a) Consumables for welding of cargo tanks shall be in accordance with *Ch 11 Approval of Welding Consumables* of the Rules for Materials and recognised Standards.

1.5.3 **Welding procedure tests for cargo tanks and process pressure vessels**

(a) Welding procedure tests for cargo tanks, secondary barriers, process pressure vessels and pressure pipework are to be qualified in accordance with *Ch 12 Welding Qualifications* of the Rules for Materials.

1.6 Specific welding requirements for liquefied petroleum gas and liquefied natural gas systems

1.6.1 **Scope**

(a) The requirements of this Section apply to welding of cargo tanks, storage tanks, containment systems, process pressure vessels and pressure piping for liquefied natural gas systems.
(b) The requirements of this Section include the welding of carbon, carbon-manganese, nickel alloy, austenitic stainless steels and aluminium alloys specified in the Rules for Materials, as suitable for use in low temperature service.
(c) The requirements of this Section are in addition to those requirements specified in *Chapter 13, Sections 1*, *4* and *5* of the Rules for Materials.

1.6.2 **Welding qualifications**

All welding procedures used during construction are to be qualified in accordance with the requirements specified in *Ch 12 Welding Qualifications* of the Rules for Materials for liquid gas applications.

1.6.3 **Production weld test frequency**

(a) For cargo tanks and process pressure vessels, except integral and membrane tanks, production weld tests shall be performed for each 50 m of butt weld joint and should be representative of each welding procedure and position used in construction.
(b) Production tests are required for secondary barriers but the number of tests required may be reduced to 1 in every 100 m of butt weld.
(c) Requirements for production testing of integral and membrane tanks are to be agreed with LR prior to manufacture.

1.6.4 **Production weld testing requirements**

(a) The type and number of specimens to be removed from each test plate for mechanical testing shall be as specified for the original welding procedure qualification test, except that:
    (i) the all weld tensile test may be omitted; and
    (ii) the number of impact tests from the heat affected zone may be reduced to sampling the location that demonstrated the lowest impact energy during procedure qualification.
(b) For independent tanks, Types A and B, the transverse tensile tests may also be omitted.
(c) The results of the mechanical tests are to meet the minimum requirements specified for the original welding procedure qualification test as specified in *Ch 12 Welding Qualifications* of the Rules for Materials.
(d) Should any impact test fail to meet requirements, consideration will be given to acceptance based on satisfactory results from two drop weight tests from the failed location. The test temperature for these shall be no higher that that specified for the impact tests and the acceptance criteria for both tests shall be no break.

1.6.5 **Non-destructive examination**

(a) All welds are to be subject to non-destructive examination in accordance with requirements specified in *Ch 4 Steel Castings* and *Ch 5 Steel Forgings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2016* unless more stringent requirements are specified below.
(b) Radiographic examination may be substituted by ultrasonic examination, *see Ch 13, 4.15 NDE Method* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2016*. In addition, ultrasonic examination may be used to augment radiographic testing for complex or critical welds.
(c) **Type A independent and semi-membrane tanks:**
    (i) where the minimum cargo design temperature is less than or equal to –20°C, the extent and type of testing shall be as for Type B tanks in (d).

(ii) where the minimum cargo design temperature is greater than –20°C, the extent and type of testing shall include 100 per cent volumetric examination of butt weld intersections, plus 10 per cent of other butt welds.

(iii) the remaining tank structure shall be subject to crack detection examination in accordance with recognised standards and the extent of examination is to be agreed with LR.

(d) **Type B independent tanks:**

Irrespective of cargo design temperature, all full penetration butt welds will be subject to 100 per cent volumetric examination. Other welds shall be subject to crack detection examination in accordance with recognised Standards and the extent of examination is to be agreed with LR.

(e) **Type C independent tanks and process pressure vessels:**

The extent of examination is dependent on the design conditions. Where the design incorporates a joint factor greater than 0,85, all butt welds will be subject to 100 per cent volumetric examination plus 10 per cent surface crack detection. Where the weld joint factor is less than or equal to 0,85, partial inspection may be considered. However, this should not be less than 10 per cent volumetric examination of full penetration butt welds, and 100 per cent surface crack detection of nozzle reinforcing rings and other vessel openings.

(f) **Integral and membrane tanks:**

Inspection is to be in accordance with recognised Standards and the extent and type of inspection is to be agreed with LR.

(g) **Secondary barrier:**

Where the outer shell of the hull is part of the secondary barrier, all sheerstrake butt welds and the intersections of all butt and seam welds in the side shell shall be examined volumetrically. The extent of inspections is to be agreed with LR.

(h) **Inner hull and independent tank structures supporting internal insulation tanks:**

Inspection requirements are to be in accordance with recognised Standards and are to be agreed with LR.

(i) **Piping**:

(i) for piping systems with design temperatures lower than –10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, piping shall be subject to 100 per cent radiographic inspection of butt-welded joints;

(ii) for butt-welded joints made using fully automatic welding procedures during pipe shop fabrication, the extent of radiographic inspection may be progressively reduced by special agreement with LR. In no case will this be reduced below 10 per cent of joints. If defects are revealed the extent of examination shall be increased to 100 per cent and will include inspection of previously accepted welds. This special approval will only be granted where the fabricator has a well-documented quality assurance system that is working effectively and will be subject to audit by LR;

(iii) for other butt-welded joints, spot radiography or other non-destructive tests shall be carried out depending on the service, position and materials. In general, at least 10 per cent of butt-welded joints of pipes should be radiographed. The extent of examination is to be agreed with LR.

1.7 Non-metallic materials

1.7.1 General

The information in the attached Appendix 1 is given for guidance in the selection and use of these materials, based on the experience to date.

Section
1 **Cargo Pressure/Temperature Control**

■ Section 1 Cargo Pressure/Temperature Control

1.1 Methods of control

1.1.1 With the exception of tanks designed to withstand full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, cargo tanks' pressure and temperature shall be maintained at all times within their design range by either one, or a combination of, the following methods:

(a) reliquefaction of cargo vapours
(b) thermal oxidation of vapours
(c) pressure accumulation
(d) liquid cargo cooling.

1.1.2 Venting of the cargo to maintain cargo tank pressure and temperature is not acceptable except in emergency situations. The Administration may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea.

1.2 Design of systems

1.2.1 Details of the proposed system of cargo pressure/temperature control are to be submitted for consideration.

The ambient temperatures for air and sea-water are to be taken at their highest daily mean temperatures for the unit's proposed area of operation based on the 100 year average return period. The ambient temperatures are to be rounded up to the nearest degree Celsius.

The ambient temperatures are not to be taken as less than 45°C for air and 32°C for sea-water unless agreed by LR.

The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

1.2.2 The system is to be tested at entry into service to prove its capability to maintain the class notation temperature and pressure.

1.3 Reliquefaction of cargo vapours

1.3.1 **General**

The reliquefaction system may be arranged in one of the following ways:

(a) A direct system where evaporated cargo is compressed, condensed and returned to the cargo tanks.
(b) An indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed.
(c) A combined system where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks.
(d) If the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases, as far as reasonably practicable, are disposed of without venting to atmosphere.

1.3.2 **Compatibility**

Refrigerants used for reliquefaction shall be compatible with the cargo they may come into contact with. In addition, when several refrigerants are used and may come into contact, they shall be compatible with each other.

1.4 Thermal oxidation of vapours

1.4.1 The use of thermal oxidation equipment on ship units engaged in the production, storage and offloading of liquefied gases in bulk at a fixed location is not anticipated, in the event that this or similar equipment is used it is to comply with Lloyd's Register's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk.*

1.5 Pressure accumulation systems

1.5.1 The containment system insulation, design pressure or both shall be adequate to provide for a suitable margin for the operating time and temperatures involved. No additional pressure and temperature control system is required.

1.6 Liquid cargo cooling

1.6.1 The bulk cargo liquid may be refrigerated by coolant circulated through coils fitted either inside the cargo tank or onto the external surface of the cargo tank.

1.7 Segregation

1.7.1 Where two or more cargoes that may react chemically in a dangerous manner are carried simultaneously, separate systems as defined in *Pt 11, Ch 1, 1.3 Definitions*, each complying with availability criteria as specified in *Pt 11, Ch 7, 1.8 Availability*, shall be provided for each cargo. For simultaneous carriage of two or more cargoes that are not reactive to each other but where, due to properties of their vapour, separate systems are necessary, separation may be by means of isolation valves.

1.8 Availability

1.8.1 The availability of the system and its supporting auxiliary services shall be such that:

(a) In case of a single failure of a mechanical nonstatic component or a component of the control systems, the cargo tanks' pressure and temperature can be maintained within their design range without affecting other essential services.
(b) Redundant piping systems are not required.
(c) Heat exchangers that are solely necessary for maintaining the pressure and temperature of the cargo tanks within their design ranges shall have a stand-by heat exchanger unless they have a capacity in excess of 25 per cent of the largest required capacity for pressure control and they can be repaired onboard without external resources. Where an additional and separate method of cargo tank pressure and temperature control is fitted that is not reliant on the sole heat exchanger, then a standby heat exchanger is not required.
(d) For any cargo heating or cooling medium, provisions shall be made to detect the leakage of toxic or flammable vapours into an otherwise non-hazardous area or overboard in accordance with *Pt 11, Ch 13, 1.6 Gas detection*. Any vent outlet from this leak detection arrangement shall be to a non-hazardous area and be fitted with a flame screen.

1.8.2 It is recommended that a reasonable margin in plant output over maximum load be allowed for possible overall inefficiencies under service conditions. It is also recommended that due regard be given to any additional capacity required to deal with cargo loading conditions.

1.8.3 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

Section 1
Vent Systems for Cargo Containment

1.1 General

1.1.1 All cargo tanks shall be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold space and interbarrier spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* shall be independent of the pressure relief systems.

1.2 Pressure relief systems

1.2.1 Cargo tanks, including deck tanks, are to be fitted with a minimum of two Pressure Relief Valves (PRVs) each being of equal size within manufacturer's tolerances and suitably designed and constructed for the prescribed service.

1.2.2 Interbarrier spaces shall be provided with pressure relief devices. Reference is made to IACS Unified Interpretation *GC9 Guidance for sizing pressure relief systems for interbarrier spaces 1988*. For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

1.2.3 The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Where two or more PRVs are fitted, valves comprising not more than 50 per cent of the total relieving capacity may be set at a pressure up to 5 per cent above MARVS to allow sequential lifting, minimising unnecessary release of vapour.

1.2.4 The following temperature requirements apply to PRVs fitted to pressure relief systems:

(a) PRVs on cargo tanks with a cargo design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation.
(b) The effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs.
(c) PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised.
(d) Sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.

1.2.5 **Valve testing**

PRVs shall be tested in accordance with a Recognised Standard or equivalent national standards. Reference is made to: ISO 21013-1 2008 – *Cryogenic vessels – Pressure-relief accessories for cryogenic service – Part 1: Reclosable pressure-relief valves*; and ISO 4126-1; 2004 *Safety devices for protection against excessive pressure – Part 1 and part 4: Safety valves*.

(a) PRVs shall be type tested. Type tests shall include:
    (i) verification of relieving capacity.
    (ii) cryogenic testing when operating at design temperatures colder than –55°C.
    (iii) seat tightness testing.
    (iv) pressure containing parts are to be pressure tested to at least 1,5 times the design pressure.
(b) Each PRV shall be tested to ensure that:
    (i) it opens at the prescribed pressure setting, with an allowance not exceeding ±10 per cent for 0 to 0,15 MPa, ±6 per cent for 0,15 to 0,3 MPa, ±3 per cent for 0,3 MPa and above.
    (ii) seat tightness is acceptable.
    (iii) pressure containing parts are to withstand at least 1,5 times the design pressure.

1.2.6 As soon as practicable prior to proceeding on gas trials, pressure relief valves are to be tested and installed in accordance with the manufacturer's recommended procedures to the Surveyor's satisfaction. Where valves are stored prior to installation on board, the storage arrangements are also to be in accordance with the manufacturer's recommended procedures.

1.2.7 PRVs shall be set and sealed by the Administration or recognised organisation acting on its behalf and a record of this action, including the valves' set pressure, shall be retained onboard the ship unit.

1.2.8 Cargo tanks may be permitted to have more than one relief valve set pressure in the following cases:

(a) installing two or more properly set and sealed PRVs and providing means as necessary for isolating the valves not in use from the cargo tank; or
(b) installing relief valves whose settings may be changed by the use of a previously approved device not requiring pressure testing to verify the new set pressure. All other valve adjustments shall be sealed.

1.2.9 Changing the set pressure under the provisions of *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.8*, and the corresponding resetting of the alarms referred to in *Pt 11, Ch 13, 1.4 Pressure monitoring 1.4.2*, shall be carried out under the supervision of the Master in accordance with approved procedures and as specified in the operating manual of the ship unit. Changes in set pressure shall be recorded in the ship unit's log and a sign shall be posted in the cargo control room if provided, in the main control area if separate from the cargo control room, and at each relief valve, stating the set pressure.

1.2.10 In the event of a failure of a cargo tank PRV a safe means of emergency isolation shall be available.

(a) Procedures are to be provided and included in the cargo operations manual (*see Pt 11, Ch 18, 1.2 Cargo operations manuals*).
(b) The procedures shall allow only one of the cargo tank's installed PRVs to be isolated.
(c) Isolation of the PRV shall be carried out under the supervision of the Master. This action shall be recorded in the ship unit's log and a sign posted in the cargo control room, if provided, and at the PRV.
(d) The tank shall not be loaded until the full relieving capacity is restored.

1.2.11 Each PRV installed on a cargo tank shall be connected to a venting system, which shall be:

(a) so constructed that the discharge will be unimpeded and directed vertically upwards at the exit.
(b) arranged to minimise the possibility of water or snow entering the vent system.
(c) arranged such that the height of vent exits shall not be less than *B*/3 or 6 m, whichever is the greater, above the weather deck.
(d) 6 m above working areas and walkways.

1.2.12 Cargo PRV vent exits shall be arranged at a distance at least equal to *B* or 25 m, whichever is less, from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

All other vent outlets connected to the cargo containment system shall be arranged at a distance of at least 10 m from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

1.2.13 All other cargo vent outlets not dealt with in other chapters shall be arranged in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.11* and *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.12*. Means shall be provided to prevent liquid overflow from vent mast outlets, due to hydrostatic pressure from spaces to which they are connected.

1.2.14 If cargoes that react in a dangerous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each one.

1.2.15 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

1.2.16 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow. Protective screens when storing pentane are also to comply with *Pt 11, Ch 17, 1.2 Flame screens on vent outlets*.

1.2.17 All vent piping shall be designed and arranged not to be damaged by; the temperature variations to which it may be exposed, forces due to flow or the motions of the ship unit.

1.2.18 PRVs shall be connected to the highest part of the cargo tank above deck level. PRVs shall be positioned on the cargo tank so that they will remain in the vapour phase at the filling limit (FL) as defined in *Pt 11, Ch 15 Filling Limits for Cargo Tanks*, under conditions of 15° list and 0,015*L* trim, where *L* is defined in *Pt 11, Ch 1, 1.3 Definitions*.

1.2.19 The adequacy of the vent system fitted on tanks loaded in accordance with *Pt 11, Ch 15, 1.5 Maximum loading limit 1.5.2*, is to be demonstrated using the *Guidelines for the Evaluation of the Adequacy of Type C Tank Vent Systems*, IMO Resolution A.829(19). A relevant certificate shall be permanently kept onboard the ship unit. For the purposes of this paragraph, vent system means:

(a) the tank outlet and the piping to the PRV.

(b) the PRV.

(c) the piping from the PRVs to the location of discharge to the atmosphere, including any interconnections and piping that joins other tanks.

1.3 Vacuum protection systems

1.3.1 Cargo tanks not designed to withstand a maximum external pressure differential 0,025 MPa, or tanks that cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by thermal oxidation, shall be fitted with:

(a) two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank and refrigeration equipment, if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or

(b) vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external design differential pressure of the cargo tank.

1.3.2 Subject to the requirements of *Pt 11, Ch 17 Special Requirements*, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimise the possibility of the entrance of water or snow *see also Pt 11, Ch 8, 1.3 Vacuum protection systems 1.3.3*. If cargo vapour is admitted it shall be from a source other than the cargo vapour lines.

1.3.3 Vacuum relief valves are not to admit air to the cargo tanks except where satisfactory controls, low pressure alarms and automatic devices for stopping cargo pumps and compressors, etc. are fitted and adjusted such that the pressure in the tanks cannot fall below a predetermined minimum safe level. Details are to be submitted for consideration.

1.3.4 The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.

1.4 Sizing of pressure relieving system

1.4.1 **Sizing of pressure relief valves**

PRVs shall have a combined relieving capacity for each cargo tank to discharge the greater of the following, with not more than a 20 per cent rise in cargo tank pressure above the MARVS:

(a) the maximum capacity of the cargo tank inerting system if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks; or

(b) vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0,82} \ (\mathrm{m}^3/_\mathrm{s})$$

where

Q = minimum required rate of discharge of air at standard conditions of 273,15 Kelvin (K) and 0,1013 MPa

F = fire exposure factor for different cargo types

F = 1,0 for tanks without insulation located on deck

F = 0,5 for tanks above the deck when insulation is approved by LR. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure)

F = 0,5 for uninsulated independent tanks installed in holds

F = 0,2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds)

F = 0,1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds)

F = 0,1 for membrane and semi membrane tanks

For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck

G = gas factor

$G = \frac{12,4}{LD}\sqrt{\frac{ZT}{M}}$

with

T = temperature in Kelvin at relieving conditions, i.e. 120 per cent of the pressure at which the pressure relief valve is set

L = latent heat of the material being vaporised at relieving conditions, in kJ/kg

D = a constant based on relation of specific heats k and is calculated as follows

$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$

k = ratio of specific heats at relieving conditions, and the value of which is between 1,0 and 2,2. If k is not known, D = 0,606 shall be used.

Z = compressibility factor of the gas at relieving conditions; if not known, Z = 1,0 shall be used.

M = molecular mass of the product.

The gas factor of each cargo to be carried shall be determined and the highest value shall be used for PRV sizing.

A = external surface area of the tank (m^2) for different tank types, as shown in *Pt 11, Ch 8, 1.4 Sizing of pressure relieving system 1.4.1*:

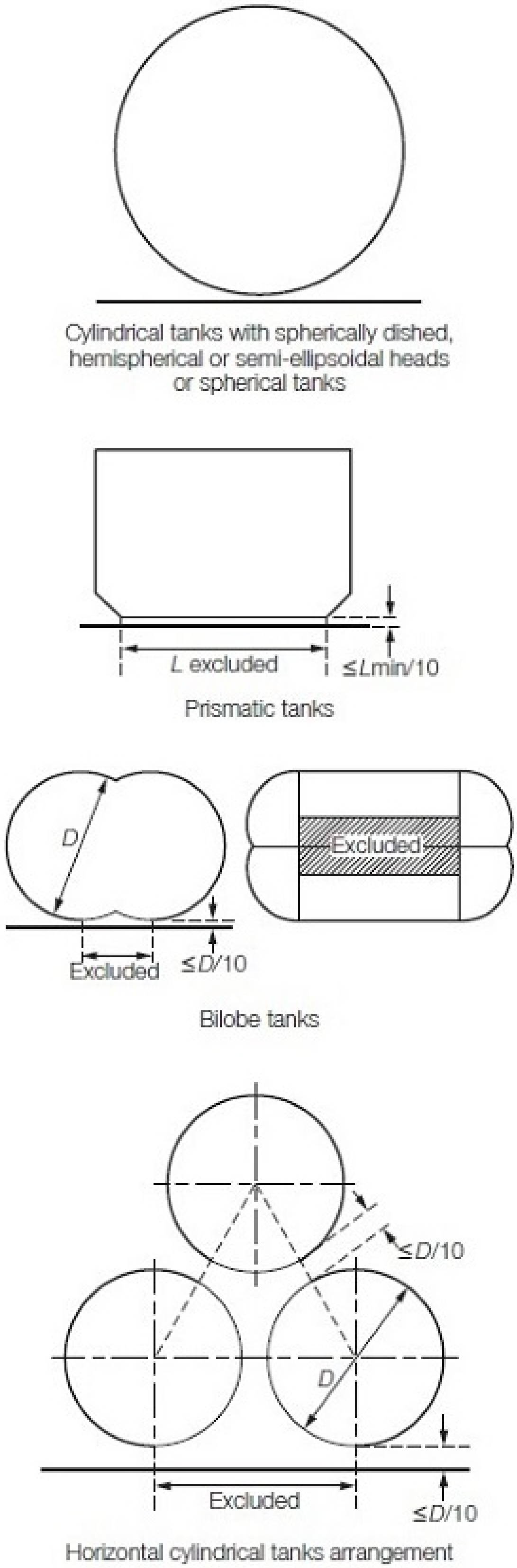


Figure 8.1.1 Horizontal cylindrical tanks arrangement

(c) The required mass flow of air at relieving conditions is given by:

$$M_{air} = Q\,\rho_{air}\ \text{(kg/s)}$$

where:

Density of air (ρ_{air}) = 1,293 kg/m^3 (air at 273,15 K, 0,1013 MPa)

1.4.2 **Sizing of vent pipe system**

As in *Pt 11, Ch 5, 1.2 System requirements 1.2.2* (d) and *Pt 11, Ch 5, 2.3 Cargo transfer arrangements 2.3.4* the relief system is to be designed in accordance with API 521 *Guide for Pressure-relieving and Depressuring Systems: Petroleum petrochemical and natural gas industries – Pressure-relieving and depressuring systems*, taking into account the following.

(a) Pressure losses upstream and downstream of the PRVs, shall be taken into account when determining their size to ensure the flow capacity required by *Pt 11, Ch 8, 1.4 Sizing of pressure relieving system 1.4.1*.

1.4.3 **Upstream pressure losses**

The pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3 per cent of the valve set pressure at the calculated flow rate, in accordance with *Pt 11, Ch 8, 1.4 Sizing of pressure relieving system 1.4.1*.

(a) Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.
(b) Pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.

1.4.4 **Downstream pressure losses**

(a) Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.
(b) The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe inter-connections that join other tanks, shall not exceed the following values:

- For unbalanced PRVs: 10 per cent of MARVS;
- For balanced PRVs: 30 per cent of MARVS;
- For pilot operated PRVs: 50 per cent of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

1.4.5 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0,02 MARVS at the rated capacity.

Section 1
Cargo Containment System Atmosphere Control

1.1 Atmosphere control within the cargo containment system

1.1.1 A piping system shall be arranged to enable each cargo tank to be safely gas freed, and to be safely filled with cargo vapour from a gas free condition. The system shall be arranged to minimise the possibility of pockets of gas or air remaining after changing the atmosphere.

1.1.2 For flammable cargoes, the system shall be designed to eliminate the possibility of a flammable mixture existing in the cargo tank during any part of the atmosphere change operation by utilising an inerting medium as an intermediate step.

1.1.3 Piping systems that may contain flammable cargoes shall comply with *Pt 11, Ch 9, 1.1 Atmosphere control within the cargo containment system 1.1.1* and *Pt 11, Ch 9, 1.1 Atmosphere control within the cargo containment system 1.1.2*.

1.1.4 A sufficient number of gas sampling points shall be provided for each cargo tank and cargo piping system to adequately monitor the progress of atmosphere change. Gas sampling connections shall be fitted with a single valve above the main deck, sealed with a suitable cap or blank. *See also Pt 11, Ch 5, 2.3 Cargo transfer arrangements 2.3.5* (e).

1.1.5 Inert gas utilised in these procedures is to be provided onboard the ship unit.

1.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks)

1.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.

1.2.2 Alternatively, subject to the restrictions specified in *Pt 11, Ch 17 Special Requirements*, the spaces referred to in *Pt 11, Ch 9, 1.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks) 1.2.1* requiring only a partial secondary barrier may be filled with dry air provided that the ship unit maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

1.2.3 For non flammable gases, the spaces referred to in *Pt 11, Ch 9, 1.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks) 1.2.1* and *Pt 11, Ch 9, 1.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks) 1.2.2* may be maintained with a suitable dry air or inert atmosphere.

1.3 Environmental control of spaces surrounding Type C independent tanks

1.3.1 Spaces surrounding cargo tanks that do not have secondary barriers shall be filled with suitable dry inert gas or dry air and be maintained in this condition with make up inert gas provided by a shipboard inert gas generation system, shipboard storage of inert gas, or with dry air provided by suitable air drying equipment. If the cargo is carried at ambient temperature, the requirement for dry air or inert gas is not applicable.

1.4 Inerting

1.4.1 Inerting refers to the process of providing a non-combustible environment. Inert gases should be compatible chemically and operationally at all temperatures likely to occur within the spaces and the cargo. The dew points of the gases shall be taken into consideration and be sufficiently low to alleviate the formation of ice or hydrates within the cargo tank or liquid pipework.

1.4.2 Where inert gas is also stored for fire-fighting purposes it shall be carried in separate containers and shall not be used for cargo services.

1.4.3 Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system shall be designed so that the temperature of the structure of the ship unit is not reduced below the limiting values imposed on it.

1.4.4 Arrangements to prevent the backflow of cargo vapour into the inert gas system that are suitable for the cargo carried, shall be provided. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves or equivalent devices and, in addition, a removable spool piece shall be fitted in the inert gas main in the cargo area. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

1.4.5 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc, shall be provided for controlling pressure in these spaces.

1.4.6 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

1.4.7 Inert gas systems are to be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

1.5 Inert gas production on board

1.5.1 The equipment shall be capable of producing inert gas with an oxygen content at no time greater than 5 per cent by volume. A continuous reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5 per cent oxygen content by volume.

1.5.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system.

1.5.3 Spaces containing inert gas generation plants shall have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. Inert gas piping shall not pass through accommodation spaces, service spaces or control stations.

1.5.4 Combustion equipment for generating inert gas shall not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using a catalytic combustion process.

Section
1 **Electrical Installations**

■ *Section 1*
Electrical Installations

1.1 General requirements

1.1.1 For the hull structure and associated liquefied gas cargo containment system, hazardous areas are to be determined, and electrical equipment is to be selected, in accordance with IEC 60092: *Electrical installations in ships – Part 502: Tankers - Special features.*

For topsides process facilities, the hazardous areas and electrical equipment selected for these areas should be established from suitable recognised hazardous area guidance, i.e. NFPA 497 *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas* or EI IP-MCSP-P15 *Model Code of Safe Practice Part 15 Area Classification Code for installations handling flammable fluids*. However, whichever Standard is selected for the classification of topsides process hazards, it should be ensured that it gives a suitably conservative determination of the defined hazardous area. Reference should also be made to the requirements stipulated within *Pt 7, Ch 2 Hazardous Areas and Ventilation*.

1.1.2 Electrical installations shall be such as to minimise the risk of fire and explosion from flammable products.

1.1.3 Electrical installations shall be in accordance with *Pt 6, Ch 2 Electrical Engineering* and *Pt 7, Ch 2 Hazardous Areas and Ventilation* where installations are located in hazardous areas. Reference is made to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999 Electrical installations in ships - Part 502: Tankers - Special features.

1.1.4 Electrical equipment or wiring should not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

1.1.5 Where electrical equipment is installed in hazardous areas as provided in *Pt 11, Ch 10, 1.1 General requirements 1.1.4* it shall be selected, installed and maintained in accordance with Standards not inferior to IEC 60092-502:1999 (*see* Clause 6, Clause 7 and Clause 9) Electrical installations in ships - Part 502: Tankers - Special features. Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognised by the Administration. Automatic isolation of non certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.

1.1.6 To facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones in accordance with recognised Standards such as *Pt 7, Ch 2, 1 Hazardous areas – General* and *Pt 7, Ch 2, 2 Classification of hazardous areas* or publication IEC 60092-502 *Electrical installations in ships - Part 502: Tankers –* Special features.

1.1.7 Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by *Pt 11, Ch 7, 1.8 Availability 1.8.1* (a), and hull structure temperature, as required by *Pt 11, Ch 4, 5.1 Materials 5.1.2*, within normal operating limits. Failure modes and effects shall be analysed and documented to a standard not inferior to IEC 60812 Analysis techniques for system reliability Procedure for failure mode and effects analysis (FMEA).

1.1.8 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be either:

(a) located in a non hazardous area; or
(b) certified for use in the hazardous area where installed in accordance with paragraph 6.5 of IEC 60092-502 Electrical installations in ships - Part 502: Tankers - Special features.

1.1.9 Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes shall be housed in gastight enclosures.

1.1.10 Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements shall be made to automatically shut down the motors in the event of low liquid level. This may be accomplished by sensing low pump discharge pressure, low motor current, or low liquid level. This shutdown shall be alarmed at the cargo control station. Cargo pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

1.1.11 Electrical equipment that is located in either enclosed or open non hazardous areas and is to remain operational during catastrophic emergency conditions (i.e. major hydrocarbon release scenarios) is to be certified for operation in Zone 1 hazardous areas. However if such emergency equipment is not certified for operation in Zone 1 hazardous areas, the continued operation of this equipment maybe acceptable if it is demonstrated that the equipment is appropriately protected against potentially coming into contact with a flammable atmosphere by being located in an enclosed non-hazardous area, with appropriate mitigating measures (i.e. enclosed non-hazardous area is equipped with gas tight barriers, gas tight doors, rated gas dampers, suitable gas detection within the enclosure and its ventilation air intakes, etc.). *See Pt 7, Ch 2, 8.1 General 8.1.6*.

1.2 Definitions

For the purpose of this Chapter, unless expressly provided otherwise, the definitions below shall apply.

1.2.1 **Hazardous area** is an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

(a) **Zone 0 hazardous area** is an area in which an explosive gas atmosphere is present continuously or is present for long periods.
(b) **Zone 1 hazardous area** is an area in which an explosive gas atmosphere is likely to occur in normal operation.
(c) **Zone 2 hazardous area** is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so infrequently and for a short period only.

1.2.2 **Non-hazardous area** is an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

1.2.3 *See also Pt 7, Ch 2, 1.2 Definitions and categories*.

Section
1 Fire Prevention and Extinction

■ Section 1
Fire Prevention and Extinction

1.1 Fire safety requirements

1.1.1 Fire prevention and fighting measures for the hull, hull weather deck and liquefied gas offloading facilities are generally to be in compliance with the following Sections, which reflect the requirements of the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code). However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), (*see Pt 7, Ch 3 Fire Safety*) dependent upon the unit's fire-fighting and safety philosophy. The various requirements of *Pt 7 SAFETY SYSTEMS, HAZARDOUS AREAS AND FIRE* should also be fully referenced in connection with fire-fighting and fire mitigating measures. When referred to in this Chapter the hull and hull weather deck are intended to include the cargo area, the machinery spaces, the accommodation, service spaces and control stations in the hull and in the superstructure, but exclude the topside facilities, process plants, external or internal turrets, if fitted, or deckhouses therein.

1.1.2 In general, the requirements for tankers in *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*are to apply to ship units covered by this Part, irrespective of tonnage of the unit, with the exception of the following:

(a) regulations *5.1 Separation of cargo oil tanks .1.6* and *5.10 Protection of cargo pump-rooms* do not apply;
(b) regulation *2 Water supply systems* as applicable to cargo ships, and regulations *4 Fixed fire-extinguishing systems* and *5 Fire extinguishing arrangements in machinery spaces* are in general to apply to the hull structure of the installation, as they would apply to tankers of 2000 gross tonnage and over;
(c) regulation *5 Fire extinguishing arrangements in machinery spaces .5.24* is to apply to the machinery spaces in the hull structure;
(d) the following regulations of *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction* related to tankers do not apply and are replaced by the Chapters and Sections of this Part as detailed below:

Regulation	Replaced by
10 Fire-fighter's outfits	*Pt 11, Ch 11, 1.6 Firefighters' outfits*
5.1 Separation of cargo oil tanks .1.1 and *5.1 Separation of cargo oil tanks .1.2*	*Pt 11, Ch 3 Ship Arrangements*
5.5 Inert gas systems	Relevant Chapters and Sections in this Part
8 Cargo tank protection	*Pt 11, Ch 11, 1.3 Water-spray system* and *Pt 11, Ch 11, 1.4 Dry chemical powder fire-extinguishing systems*
9 Protection of cargo pump rooms in tankers	*Pt 11, Ch 11, 1.5 Enclosed spaces containing cargo handling equipment*
2 Water supply systems	*Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.1* to *Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.6*

(e) regulations *3.4 Emergency escape breathing devices* and *4.3 Emergency escape breathing devices* shall apply to the hull and hull weather deck.

1.1.3 Emergency escape breathing devices, in addition to those required by *Pt 11, Ch 11, 1.1 Fire safety requirements 1.1.2*, should be available as determined by the escape, evacuation and rescue analysis of the unit.

1.1.4 In the hull, all sources of ignition should be excluded from spaces where flammable vapour may be present, except as otherwise provided in *Pt 11, Ch 10 Electrical Installations* and *Pt 11, Ch 16 Use of Cargo as Fuel*. For the topsides areas of the unit, sources of ignition should be minimised where practicable, but must always be certified for any defined hazardous area in which it is intended to operate. *See also Pt 7, Ch 1 Safety and Communication Systems* and *Pt 7, Ch 2 Hazardous Areas and Ventilation* with regard to mitigation of ignition risks.

1.1.5 The provisions of this Section apply in conjunction with *Pt 11, Ch 3 Ship Arrangements*.

1.1.6 For the purposes of fire fighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area.

1.2 Fire mains and hydrants

1.2.1 All ship units, irrespective of size, with bulk liquefied gas storage and/or vapour discharge and loading manifolds/ facilities, carrying products specified in *Pt 11, Ch 19 Summary of Minimum Requirements* are in general to comply with the requirements of SOLAS regulations *2 Water supply systems*, except that the required fire pump capacity and fire main and water service pipe diameter should not be limited by the provisions of regulations *2.2 Fire pumps .2.18* and *2.1 Fire mains and hydrant . 1.5*. When a fire pump is used as part of the water spray system, as permitted by *Pt 11, Ch 11, 1.3 Water-spray system 1.3.3* of this Chapter, the capacity of this fire pump shall be such that these areas can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 5,0 bar gauge for hydrants located at hull, hull weather deck and liquefied gas offloading facilities. For hydrant located on topsides facilities, the pressure should be at least 3,5 bar gauge for two operational hydrants at the hydrant outlet valve upstream of the utilised hydrant hose.

1.2.2 In addition to *Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.1*, the fire pump capacity and fire main should be sized to supply all credible fire water demands associated with a credible installation fire scenario determined via the Fire and Explosion Evaluation (FEE).

1.2.3 For the purpose of application of *Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.6*, the capability to remain functional is to be regarded as the ability of the system to perform its function after exposure to the indicated temperature. That may be demonstrated using components and materials of suitable characteristics and of an approved type, where applicable.

1.2.4 The arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area, those portions of the cargo containment system and tank covers that are above the deck, and topside areas. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of SOLAS regulations *2.1 Fire mains and hydrant .1.13* and *2.3 Fire hoses and nozzles .3.8*, taking into account the length of the hoses used at the location. The hose length should not be greater than 15 m in hull machinery spaces and should not be greater than 20 m in topsides areas, due to space constraints to enable the hose to be laid out by a fire team in a fire incident. In addition, the requirements of regulation *2.1 Fire mains and hydrant .1.15* shall be met at a pressure of at least 5.0 bar gauge at the hydrant outlet valve upstream of the utilised hydrant hose.

1.2.5 Stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that regulation *Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.4* can be complied with using not more than two lengths of hoses from the nearest fire hydrant. The water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned outside the cargo area. The main installation firewater pumps are to be positioned to ensure a high degree of firewater pump redundancy and firewater supply integrity in potential major installation fire scenarios.

1.2.6 All nozzles provided for fire hoses shall be of an approved dual purpose type, capable of producing either a spray or a jet. All pipes, valves, nozzles and other fittings in the fire fighting systems shall be resistant to corrosion by sea water. Fixed piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C and remain functional.

1.2.7 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

1.3 Water-spray system

1.3.1 A water application system, which may be based on water-spray nozzles, for cooling, fire prevention and crew protection shall be installed to cover:

(a) exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks;
(b) exposed on-deck storage vessels for flammable or toxic products;
(c) gas process units, positioned on deck;
(d) cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided;
(e) all exposed emergency shut down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers;

(f) exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire risk items or equipment do not require water-spray protection;

(g) any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room.

1.3.2 The system shall be capable of covering all areas mentioned in *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* with a uniformly distributed water application rate of at least 10 l/m^2/minute for the largest projected horizontal surfaces and 4 l/m^2/minute for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water application shall not be less than the projected horizontal surface multiplied by 10 l/m^2/minute.

On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted in the spray water application main supply line(s), at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position outside of the cargo area. A section protecting any area included in *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* (a) and (b) shall cover at least the entire athwartship tank grouping in that area. Any gas process unit(s) included in *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* (c) may be served by an independent section.

1.3.3 The capacity of the water application pumps shall be capable of simultaneous protection of any two complete athwartship tank groupings, including any gas process units within these areas in addition to surfaces specified in *Pt 11, Ch 11, 1.3 Water-spray system 1.3.1* (d) to (g). Alternatively, the main fire pumps may be used for this service provided that their total capacity is increased by the amount needed for the water-spray application system. In either case a connection, through a stop valve, shall be made between the fire main and waterspray application system main supply line outside of the cargo area. *See also Pt 11, Ch 11, 1.2 Fire mains and hydrants 1.2.2*.

1.3.4 The maximum credible firewater demand should be determined in the installation Fire and Explosion Evaluation (FEE) based on the credible activation of water spray systems detailed in this section and any additional topside module and hydrant demands. The installation main firewater pumps should be sized suitably to supply the defined maximum credible firewater demand. The installation design should incorporate a suitable allowance for firewater pump redundancy. This redundancy is to allow for failure of a firewater pump on demand or loss of a firewater pump for maintenance without incurring potential lost production on the installation due to the loss of firewater supply. Permanently manned hydrocarbon installations typically have two 100 per cent or three 50 per cent firewater pumps designed to meet the installation's defined largest credible firewater demand scenario (i.e. the installation's 100 per cent firewater demand). However, other configurations of firewater pump supply redundancy may be acceptable for an installation, subject to suitable demonstration (for example, normally unmanned installations often do not have any dedicated firewater pumps).

1.3.5 Water pumps normally used for other services may be arranged to supply the water-spray application system main supply line. However, the suitability and reliability of any such pump would need to be demonstrated as equal to that required by a defined firewater pump.

1.3.6 All pipes, valves, nozzles and other fittings in the water application systems shall be resistant to corrosion by seawater. Galvanised pipework may be considered for this service but copper nickel alloy or stainless steel pipework which is rated for marine/sea-water/fire-fighting service is recommended for installations. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C. The water application system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition means shall be provided to back flush the system with fresh water.

1.3.7 Remote starting of pumps supplying the water application system and remote operation of any normally closed valves in the system shall be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the protected areas.

1.3.8 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

1.3.9 The provision of fixed firewater fire-fighting facilities over topsides process module areas should be established based on the fire-fighting risks and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

1.4 Dry chemical powder fire-extinguishing systems

1.4.1 Dependent upon the conclusions of the Fire and Explosion Evaluation (FEE) and the installation's fire-fighting and safety philosophy, consideration for ship units should be given to the provision of fixed dry chemical powder fire-extinguishing systems, complying with the provisions of the Guidelines developed by IMO (IMO (MSC.1/Circ. 1315)), for the purpose of fire-fighting on the deck in the cargo area, including all cargo liquid and vapour discharge and loading connections on deck and cargo handling areas

as applicable. Should a system not be fitted as a result of the conclusions mentioned above, final acceptance of the proposal should be to the satisfaction of the Flag Administration, if applicable.

1.4.2 The system shall be capable of delivering powder from at least two hand hose lines, or a combination of monitor/hand hose lines, to any part of the exposed cargo area, cargo liquid and vapour piping, load/unload connections and exposed gas process units.

1.4.3 The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by *Pt 11, Ch 11, 1.4 Dry chemical powder fire-extinguishing systems 1.4.2* shall be capable of being reached from not less than two independent units with associated controls, pressurising medium fixed piping, monitors or hand hose lines. A monitor shall be arranged to protect any load/unload connection areas and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed if it can deliver the necessary powder to all required areas of coverage from a single position. One hose line shall be provided at both port and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.

1.4.4 A fire-extinguishing unit having two or more monitors, hand hose lines, or combinations thereof, should have independent pipes with a manifold at the powder container, unless alternative means are provided, with a level of performance acceptable to LR. Where two or more pipes are attached to a unit the arrangement should be such that any or all of the monitors and hand hose lines should be capable of simultaneous or sequential operation at their rated capacities. The components associated with the dry chemical powder fire-extinguishing system(s) are to be in accordance with an acceptable national or international standard, and be of an approved type where appropriate.

1.4.5 The capacity of a monitor shall be not less than 10 kg/s. Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3,5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidised state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.

1.4.6 Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration shall be given where areas to be protected are substantially higher than the monitor or hand hose reel locations.

1.4.7 Ship units fitted with bow, stern load/unload connections shall be provided with independent dry powder units protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow, stern load/unload complying with the requirements of *Pt 11, Ch 11, 1.4 Dry chemical powder fire-extinguishing systems 1.4.1* to *Pt 11, Ch 11, 1.4 Dry chemical powder fire-extinguishing systems 1.4.6*.

1.4.8 After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. All distribution piping shall be blown through with dry air to ensure that the piping is free of obstructions.

1.5 Enclosed spaces containing cargo handling equipment

1.5.1 Enclosed spaces meeting the criteria of cargo machinery spaces in *Pt 11, Ch 1, 1.3 Definitions 1.3.1* (j), and the cargo motor room within the cargo area of any ship unit, shall be provided with a fixed fire extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires.

1.5.2 Cargo machinery spaces shall be protected by an appropriate fire-extinguishing system for the cargo carried. The system is to be of a type acceptable to LR, and approved by the unit's Flag Administration (if applicable).

1.5.3 The fire risks associated with the turret compartments of any ship unit are to be fully assessed within the installation Fire and Explosion Evaluation (FEE). The firefighting/ mitigating measures associated with the turret (i.e. water spray, passive fire protection, isolation and blowdown, etc.) are to be based upon the fire risks determined within the Fire and Explosion Evaluation (FEE) and should be in line with the overall installation's fire-fighting and safety philosophy.

1.6 Firefighters' outfits

1.6.1 In addition to the requirements outlined in this Section, further facilities may be required on the installation based on the fire-fighting risks and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

1.6.2 Every ship unit shall carry firefighter's outfits complying with the requirements of SOLAS regulation *10 Fire-fighter's outfits* as follows:

Total cargo capacity	Number of outfits
5000 m^3 and below	4
Above 5000 m^3	5

1.6.3 Additional requirements for safety equipment are given in *Pt 11, Ch 14 Personnel Protection*.

1.6.4 Any breathing apparatus required as part of a firefighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1200 l of free air.

1.7 Passive Fire protection systems

1.7.1 In addition to *Pt 7, Ch 3, 3.6 Passive fire protection*, Passive Fire Protection Systems and their components, when installed in locations where they may be exposed to releases of cryogenic products, should take into account the impact of such release on their performance and rating.

■ Section 1
Artificial Ventilation in the Cargo Area

1.1 Spaces required to be entered during normal cargo handling operations

The requirements of this Chapter replace the requirements SOLAS Regulations *5.2 Restriction on boundary openings .2.6* and *5.4 Ventilation .4.1*, as amended.

1.1.1 Electric motor rooms, cargo compressor and pump rooms, spaces containing cargo handling equipment and other enclosed spaces where cargo vapours may accumulate shall be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces. The ventilation shall be run continuously to prevent the accumulation of toxic and/or flammable vapours, with a means of monitoring acceptable to the Administration to be provided. A warning notice requiring the use of such ventilation prior to entering shall be placed outside the compartment.

1.1.2 Artificial ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid accumulation of flammable, toxic or asphixiant vapours, and to ensure a safe working environment.

1.1.3 The ventilation system shall have a capacity of not less than 30 changes of air per hour, based upon the total volume of the space. As an exception, non-hazardous cargo control rooms may have eight changes of air per hour.

1.1.4 Where a space has an opening into an adjacent more hazardous space or area, it shall be maintained at an over-pressure. It may be made into a less hazardous space or non-hazardous space by over-pressure protection in accordance with recognised Standards such as IEC 60092-502:1999 *Electrical installations in ships - Part 502: Tankers – Special features.* Where the hazard in the adjacent more hazardous space is a potential flammable or explosive gas air mixture, and the space in question is to be classified as a non-hazardous or less hazardous area as per hazardous area classification see *Pt 7, Ch 2, 2 Classification of hazardous areas*, the adjacent more hazardous space shall be maintained with an underpressure of at least 50 Pa in relation to the space in question, to comply with *Pt 7, Ch 2, 6.2 Ventilation of hazardous spaces 6.2.2* .

1.1.5 Ventilation ducts, air intakes and exhaust outlets serving artificial ventilation systems shall be positioned in accordance with recognised Standards.

1.1.6 Ventilation ducts serving hazardous areas shall not be led through accommodation, service and machinery spaces or control stations, except as allowed in *Pt 11, Ch 16 Use of Cargo as Fuel*.

1.1.7 Electric motors driving fans shall be placed outside the ventilation ducts that may contain flammable vapours. Ventilation fans shall not produce a source of ignition in either the ventilated space or the ventilation system associated with the space. For hazardous areas, ventilation fans and ducts, adjacent to the fans shall comply with *Pt 7, Ch 2, 5.1 General 5.1.2* and be of non sparking construction, as defined below:

(a) impellers or housing of non-metallic construction, with due regard being paid to the elimination of static electricity;
(b) impellers and housing of non-ferrous materials;
(c) impellers and housing of austenitic stainless steel; and
(d) ferrous impellers and housing with not less than 13 mm design tip clearance.

Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.

1.1.8 Where fans are required by this Chapter, full required ventilation capacity for each space shall be available after failure of any single fan or spare parts shall be provided comprising; a motor, starter spares and complete rotating element, including bearings of each type.

1.1.9 Protection screens of not more than 13 mm square mesh shall be fitted to outside openings of ventilation ducts.

1.1.10 Where spaces are protected by pressurisation the ventilation shall be designed and installed in accordance with recognised Standards.

1.1.11 For *Pt 11, Ch 12, 1.1 Spaces required to be entered during normal cargo handling operations 1.1.5* to *Pt 11, Ch 12, 1.1 Spaces required to be entered during normal cargo handling operations 1.1.10* reference is made to the recommendation published by the International Electrotechnical Commission: in particular to the publication IEC 60092-502:1999.

1.2 Spaces not normally entered

1.2.1 Enclosed spaces where cargo vapours may accumulate shall be capable of being ventilated to ensure a safe environment when entry into them is necessary. This shall be capable of being achieved without the need for prior entry.

1.2.2 Ventilation systems are to be capable of use prior to entry and during occupation. For permanent installations, the capacity of 8 air changes per hour shall be provided and for portable systems, the capacity of 16 air changes per hour.

Fans or blowers shall be clear of personnel access openings, and shall comply with*Pt 11, Ch 12, 1.1 Spaces required to be entered during normal cargo handling operations 1.1.7*.

1.2.3 Enclosed spaces in the cargo area used as laboratories, workshops, decontamination cubicles or for domestic purposes are to comply with the requirements of *Pt 11, Ch 12, 1.1 Spaces required to be entered during normal cargo handling operations 1.1.1*.

1.2.4 Particulars of the type and number of portable fans, their arrangements and means of attachment are to be submitted for consideration in relation to the internal and external arrangements of the space concerned.

Section
1 Instrumentation and Automation Systems

Section 1
Instrumentation and Automation Systems

1.1 General

1.1.1 Where safety applications are to be implemented, the requirements of IEC 61508, *Functional safety of electrical/ electronic/programmable electronic safety-related systems* or alternative relevant International or National Standard, shall be used. *See Pt 7, Ch 1, 7.1 General 7.1.15*.

1.1.2 Each cargo tank shall be provided with a means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigeration installations.

1.1.3 If loading and unloading of the ship unit is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank shall be concentrated in one control position.

1.1.4 Instruments shall be tested to ensure reliability under the working conditions. Test procedures for instruments and the intervals between testing and recalibration shall be in accordance with manufacturer's recommendations, or at a period developed by risk assessment.

1.2 Level indicators for cargo tanks

1.2.1 Each cargo tank shall be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the cargo tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.

1.2.2 Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

1.2.3 Cargo tank liquid level gauges may be of the following types, subject to special requirements for particular cargoes shown in column ‘g’ in *Table 19.1.2 Explanatory notes to the summary of minimum requirements* :

(a) indirect devices, which determine the amount of cargo by means such as weighing or in-line flow metering;
(b) closed devices, which do not penetrate the cargo tank, such as devices using radio-isotopes or ultrasonic devices;
(c) closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If a closed gauging device is not mounted directly on to the tank, it shall be provided with a shutoff valve located as close as possible to the tank.
(d) restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1,5 mm diameter or equivalent area unless the device is provided with an excess flow valve.

1.3 Overflow control

1.3.1 Each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

1.3.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full.

1.3.3 The emergency shutdown valve referred to in *Pt 11, Ch 5, 2.2 Cargo system valve requirements* and *Pt 11, Ch 18, 4 Linked emergency shutdown (ESD) system* may be used for this purpose. If another valve is used for this purpose, the same information as referred to in *Pt 11, Ch 18, 4.2 ESD valve requirements 4.2.1* (c) shall be available onboard. During loading,

whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, alternative arrangements such as limiting the loading rate shall be used.

1.3.4 The position of the sensors in the tank shall be capable of being verified before commissioning. At first loading, and after each dry-docking, testing of high level alarms shall be conducted by raising the cargo liquid level in the cargo tank to the alarm point.

1.3.5 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to cargo operation in accordance with *Pt 11, Ch 18, 2.3 Cargo transfer operations 2.3.2*.

1.4 Pressure monitoring

1.4.1 The vapour space of each cargo tank shall be provided with a direct reading gauge. Additionally, an indirect indication is to be provided at the control position required by *Pt 11, Ch 13, 1.1 General 1.1.2*. Maximum and minimum allowable pressures shall be clearly indicated.

1.4.2 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigating bridge and at the control position required by *Pt 11, Ch 13, 1.1 General 1.1.2*. Alarms shall be activated before the set pressures are reached.

1.4.3 For cargo tanks fitted with PRVs, which can be set at more than one set pressure in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.8*, high-pressure alarms shall be provided for each set pressure. A permit to work system advising which PRV setting is in use is to be provided.

1.4.4 Each cargo-pump discharge line and each liquid and vapour cargo manifold shall be provided with at least one pressure indicator.

1.4.5 Local-reading manifold pressure indication shall be provided to indicate the pressure between manifold valves of the ship unit and hose connections to the shuttle tanker.

1.4.6 Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indication.

1.4.7 All pressure indications provided shall be capable of indicating throughout the operating pressure range.

1.5 Temperature indicating devices

1.5.1 Each cargo tank shall be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The lowest temperature for which the cargo tank has been designed, consistent with the assigned class notation, shall be clearly indicated by means of a sign on or near the temperature indicating devices.

1.5.2 The temperature indicating devices shall be capable of providing temperature indication across the expected cargo operating temperature range of the cargo tanks.

1.5.3 Where thermowells are fitted they shall be designed to minimise failure; due to fatigue in normal service.

1.6 Gas detection

1.6.1 Gas detection equipment shall be installed to monitor the integrity of the cargo containment, cargo handling and ancilliary systems in accordance with this Section. However, the overall provision of gas detection on the installation should be defined based on ignition risk mitigating measures and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

1.6.2 A permanently installed system of gas detection and audible and visual alarms shall be fitted in:

(a) all enclosed cargo and cargo machinery spaces (including turrets compartments) or similar enclosures containing gas piping, gas equipment or gas consumers;
(b) other enclosed or semi-enclosed spaces where cargo vapours may accumulate including interbarrier spaces and hold spaces for independent tanks other than Type C;
(c) airlocks;
(d) the spaces in gas fired internal combustion engines, referred to in *Pt 11, Ch 16, 4.2 Special requirements for gas-fired internal combustion engines 4.2.4* (c);
(e) ventilation hoods and gas ducts required by *Pt 11, Ch 16 Use of Cargo as Fuel*;

(f) cooling/heating circuits, as required by *Pt 11, Ch 7, 1.8 Availability 1.8.1* (d);
(g) inert gas generator supply headers;
(h) motor rooms for cargo handling machinery.

The various fire and gas detectors should feed signals into a robust fire and gas detection system/panel, in accordance with the requirements of *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems*. High level fire and gas signals, along with process hazard signals are then to feed into a robust Emergency Shut-down (ESD) System, in accordance with the requirements of *Pt 11, Ch 18 Operating Requirements* and*Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems*.

1.6.3 Gas detection equipment shall be designed, installed and tested in accordance with IEC 60079-29-1 – *Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable gases* and shall be suitable for the cargoes to be stored in accordance with column 'f' in table of*Pt 11, Ch 19 Summary of Minimum Requirements*.

1.6.4 For ship units permitted to store non-flammable products, oxygen deficiency monitoring shall be fitted in cargo machinery spaces and cargo tank hold spaces. Furthermore, oxygen deficiency monitoring equipment shall be installed in enclosed or semi-enclosed spaces containing equipment that may cause an oxygen-deficient environment such as nitrogen generators, inert gas generators or nitrogen cycle refrigerant systems.

1.6.5 Permanently installed gas detection shall be of the continuous detection type, capable of immediate response. Where not used to activate safety shutdown functions required by *Pt 11, Ch 13, 1.6 Gas detection 1.6.7* and *Pt 11, Ch 16 Use of Cargo as Fuel*, the sampling type detection may be accepted.

1.6.6 When sampling type gas detection equipment is used the following requirements shall be met:

(a) the gas detection equipment shall be capable of continuous monitoring at each sampling head location; and
(b) individual sampling lines from sampling heads to the detection equipment shall be fitted; and
(c) pipe runs from sampling heads shall not be led through non-hazardous spaces except as permitted by *Pt 11, Ch 13, 1.6 Gas detection 1.6.7*.

1.6.7 The gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure shall be continuously monitored. At gas concentrations of 20 per cent lower flammable limit (LFL) inside the enclosure an alarm shall be activated in accordance with the requirements of *Pt 11, Ch 13, 1.6 Gas detection 1.6.13* via the fire and gas system. At gas concentrations above 30 per cent lower flammable limit (LFL) inside the enclosure, the gas detection equipment is to be automatically shut down but the alarm in accordance with *Pt 11, Ch 13, 1.6 Gas detection 1.6.13* is to be maintained until gas concentrations drop below 20 per cent lower flammable limit (LFL) inside the enclosure.

1.6.8 Where the enclosure cannot be arranged directly on the forward bulkhead, sample pipes shall be of steel or equivalent material and are to be routed on their shortest way. Detachable connections, except for the connection points for isolating valves required in *Pt 11, Ch 13, 1.6 Gas detection 1.6.10* and analysing units, are not permitted.

1.6.9 In liquefied gas storage spaces, including cargo hold spaces, the sampling heads are not to be located where bilge water can collect.

1.6.10 When gas sampling equipment is located in non-hazardous space, a flame arrester and a manual isolating valve shall be fitted in each of the gas sampling lines. The isolating valve shall be fitted on the non-hazardous side. Bulkhead penetrations of sample pipes between hazardous and non-hazardous areas shall maintain the integrity of the division penetrated. The exhaust gas shall be discharged to the open air in a non-hazardous location.

1.6.11 Gas analysing equipment and associated sampling pumps and solenoid valves located in a gas-safe space are to be enclosed in a gastight steel cabinet, monitored by its own sampling point. At gas concentrations of 20 per cent lower flammable limit (LFL) inside the enclosure, an alarm is to be activated in accordance with the requirements of *Pt 11, Ch 13, 1.6 Gas detection 1.6.13* via the fire and gas system. At gas concentrations above 30 per cent LFL inside the steel cabinet the entire gas analysing unit is to be automatically shut down but the alarm in accordance with *Pt 11, Ch 13, 1.6 Gas detection 1.6.13* is to be maintained until gas concentrations drop below 20 per cent lower flammable limit (LFL) inside the enclosure.

1.6.12 In every installation, the number and the positions of detection heads shall be determined with due regard to the size and layout of the compartment, the compositions and densities of the products intended to be carried and the dilution from compartment purging or ventilation and stagnant areas.

1.6.13 Any alarms status within a gas detection system required by this Section shall initiate an audible and visible alarm;

(a) on the navigation bridge (if provided on the installation);

(b) at the relevant control station(s) where continuous monitoring of the gas levels is recorded; and

(c) at the gas detector readout location.

1.6.14 In the case of flammable products, the gas detection equipment provided for hold spaces and interbarrier spaces that are required to be inerted shall be capable of measuring gas concentrations of 0 per cent to 100 per cent by volume.

1.6.15 For membrane containment systems, the primary and secondary insulation spaces are to have independent inert gas systems and independent gas detection systems. The alarm in the secondary insulation space shall be set at 30 per cent of the LFL in air, that in the primary space shall be set at a value approved by LR.

1.6.16 For other spaces described by *Pt 11, Ch 13, 1.6 Gas detection 1.6.2*, alarms are to be activated when the vapour concentration reaches a relatively low per cent LFL (typically 20 per cent of the LFL in air). The fire and gas detection system stipulated by *Pt 7, Ch 1, 2 Fire and gas alarm indication and control systems* shall initiate safety functions required by *Pt 11, Ch 18 Operating Requirements* and *Pt 7, Ch 1, 7 Emergency shutdown (ESD) systems* if the vapour concentration reaches 60 per cent LFL. However, for gas detection within ventilation ducts, a low level alarm setting of 10 per cent of the LFL in air is to be utilised, due to the potential to generate laminar flow within ductwork. Within turbine hoods and other spaces with potential high air change rates, a low level alarm setting of 10 per cent of the LFL shall be utilised with initiation of emergency shut-down actions if vapour concentrations rates 20 per cent of the LFL. The crankcases of internal combustion engines that can run on gas shall be arranged to alarm before 100 per cent LFL.

1.6.17 Gas detection equipment shall be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment for this purpose shall be carried on board and be used in accordance with the manufacturer's recommendations. Permanent connections for such test equipment shall be fitted.

1.6.18 Every ship unit shall be provided with at least two sets of portable gas detection equipment that meet the requirement of *Pt 11, Ch 13, 1.6 Gas detection 1.6.3* or an acceptable national or international Standard.

1.6.19 A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.

1.6.20 For FLNG Units with hull bulk storage tanks for hydrocarbons other than bulk liquefied gases (e.g. condensate etc.). A suitable fixed hydrocarbon gas detection system for adjacent ballast tanks and void spaces of double-hull and double bottom spaces adjacent to these storage tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to these tank spaces shall be fitted. The design of this fixed gas detection system shall be in accordance with the requirements of *Chapter 16 - Fixed Hydrocarbon Gas Detection Systems* of the *FSS Code - Fire Safety Systems – Resolution MSC.98(73)*.

1.7 Additional requirements for containment systems requiring a secondary barrier

1.7.1 **Integrity of barriers**

Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall consist of appropriate gas detecting devices according to *Pt 11, Ch 13, 1.6 Gas detection*. However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

1.7.2 Temperature indication devices

(a) The number and position of temperature indicating devices shall be appropriate to the design of the containment system and cargo operation requirements.

(b) When cargo is carried in a cargo containment system with a secondary barrier, at a temperature lower than –55°C, temperature indicating devices shall be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals and, where applicable, alarm of temperatures approaching the lowest for which the hull steel is suitable.

(c) If cargo is to be carried at temperatures lower than –55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, shall be fitted with a sufficient number of temperature indicating devices to verify that unsatisfactory temperature gradients do not occur.

(d) For the purposes of design verification and determining the effectiveness of the initial cooldown procedure, one tank shall be fitted with devices in excess of those required in (a). These devices may be temporary or permanent.

1.8 Automation systems

1.8.1 The requirements of this Section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by this Part.

1.8.2 Automation systems shall be designed, installed and tested in accordance with recognised Standards.

1.8.3 Hardware shall be capable of being demonstrated to be suitable for use in the marine environment by type approval or other means.

1.8.4 Software shall be designed and documented for ease of use, including testing, operation and maintenance.

1.8.5 The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.

1.8.6 Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.

1.8.7 Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the Automation Systems that are required to provide specified functions, including connected devices and power supplies.

1.8.8 Automation Systems shall be arranged such that the configuration is protected against unauthorised or unintended change.

1.8.9 A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained onboard.

1.8.10 Processes for the development and maintenance of integrated systems shall be in accordance with recognised Standards. These processes shall include appropriate risk identification and management.

1.9 System integration

1.9.1 Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the administration, both in normal operation and under fault conditions. Functions shall be designed to fail safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by all relevant stakeholders.

1.9.2 Functional requirements of each component subsystem shall be clearly defined to ensure that the integrated system meets functional and specified safety requirements and takes account of any limitations of the equipment under control.

1.9.3 Key hazards of the integrated system shall be identified using appropriate risk based techniques.

1.9.4 The integrated system shall have a suitable means of reversionary control.

1.9.5 Failure of one part of the integrated system shall not affect the functionality of other parts except for those functions directly dependent on the defective part.

1.9.6 Operation with an integrated system shall be at least as effective as it would be with individual stand alone equipment or systems.

1.9.7 The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated.

Section
1 Personnel Protection

Section 1
Personnel Protection

1.1 Protective equipment

1.1.1 The requirements of this Chapter are not classification requirements. However, in cases where Lloyd's Register (LR) is requested to do so by an Owner, Operator or Duty Holder, the requirements of this Chapter will be applied, together with any amendments or interpretations adopted by the appropriate National Authority.

1.1.2 The requirements of this Chapter are considered to be minimum requirements applicable to installations with bulk liquefied gas storage and/or vapour discharge and loading/offloading manifolds/facilities. However, additional equipment for personnel protection above the requirements outlined within this Chapter may be required on an installation and these should be defined as part of the risk mitigating measures and philosophy derived for the installation.

1.1.3 Suitable protective equipment, including eye protection to a recognised National or International Standard, shall be provided for protection of crew members engaged in normal cargo operations, taking into account the characteristics of the products being carried.

1.1.4 Personal protective and safety equipment required in this chapter shall be kept in suitable, clearly marked lockers located in readily accessible places.

1.1.5 The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection logged in the ship unit's records. This equipment shall also be inspected and tested by a competent person at least once a year.

1.2 First-aid equipment

1.2.1 A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.

1.2.2 The ship unit shall have onboard medical first aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for the intended cargoes.

1.3 Safety equipment

1.3.1 Sufficient, but not less than three complete sets of safety equipment shall be provided in addition to the firefighter's outfits required by *Pt 11, Ch 6, 1.6 Specific welding requirements for liquefied petroleum gas and liquefied natural gas systems 1.6.2*. Each set shall provide adequate personal protection to permit entry and work in a gas-filled space. This equipment shall take into account the nature of the intended cargoes.

1.3.2 Each complete set of safety equipment shall consist of:

(a) one self contained positive pressure air breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1 200 litres of free air. Each set shall be compatible with that required by *Pt 11, Ch 6, 1.6 Specific welding requirements for liquefied petroleum gas and liquefied natural gas systems 1.6.2*.
(b) protective clothing, boots and gloves to a recognised standard.
(c) steel cored rescue line with belt; and
(d) explosion proof lamp.

1.3.3 An adequate supply of compressed air shall be provided and shall consist of:

(a) At least one fully charged spare air bottle for each breathing apparatus required by *Pt 11, Ch 14, 1.3 Safety equipment 1.3.1*, in accordance with the requirements of *Pt 11, Ch 6, 1.6 Specific welding requirements for liquefied petroleum gas and liquefied natural gas systems 1.6.2*;
(b) an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high pressure air of breathable quality, and

(c) a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by *Pt 11, Ch 14, 1.3 Safety equipment 1.3.1*.

Section 1
Filling Limits for Cargo Tanks

1.1 Definitions

1.1.1 **Filling limit (FL)** means the maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature.

1.1.2 **Loading limit (LL)** means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

1.1.3 Reference temperature means (for the purposes of this Chapter only):

(a) When no cargo vapour pressure/temperature control, as referred to in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* , is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs.
(b) When a cargo vapour pressure/temperature control, as referred to in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* , is provided, the temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greatest.

1.1.4 Ambient design temperatures for air and seawater are at their highest daily mean temperatures for the unit's proposed area of operation based on the 100 year average return period. The ambient temperatures are to be rounded up to the nearest degree Celsius. For initial design, the ambient temperatures may be taken as 45°C for air and 32°C for sea-water.

1.2 General requirements

1.2.1 The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:

(a) tolerance of instrumentation such as level and temperature gauges
(b) volumetric expansion of the cargo between the PRV set pressure and the maximum allowable rise stated in *Pt 11, Ch 8, 1.4 Sizing of pressure relieving system*
(c) an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, *see Pt 11, Ch 5, 2.2 Cargo system valve requirements* and *Pt 11, Ch 18, 4.2 ESD valve requirements 4.2.1* (d).

1.3 Default filling limit

1.3.1 The default value for the filling limit (FL) of cargo tanks is 98 per cent at the reference temperature. Exceptions to this value shall meet the requirements of *Pt 11, Ch 15, 1.4 Determination of increased filling limit*.

1.4 Determination of increased filling limit

1.4.1 A filling limit greater than the limit of 98 per cent specified in *Pt 11, Ch 15, 1.3 Default filling limit* on condition that, under the trim and list conditions specified in *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.18* may be permitted, providing:

(a) no isolated vapour pockets are created within the cargo tank
(b) the PRV inlet arrangement shall remain in the vapour space
(c) allowances need to be provided for:
    (i) volumetric expansion of the liquid cargo due to the pressure increase from the MARVS to full flow relieving pressure in accordance with *Pt 11, Ch 8, 1.4 Sizing of pressure relieving system 1.4.1*
    (ii) an operational margin of minimum 0,1 per cent of tank volume
    (iii) tolerances of instrumentation such as level and temperature gauges.

1.4.2 In no case shall a filling limit exceeding 99,5 per cent at reference temperature be permitted.

1.5 Maximum loading limit

1.5.1 The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:

$$LL = FL\frac{\rho_R}{\rho_L}$$

where:

LL = loading limit as defined in *Pt 11, Ch 15, 1.1 Definitions 1.1.2* expressed in per cent;

FL = filling limit as specified in *Pt 11, Ch 15, 1.3 Default filling limit* or *Pt 11, Ch 15, 1.4 Determination of increased filling limit* expressed in per cent;

ρ_R = relative density of cargo at the reference temperature; and

ρ_L = relative density of cargo at the loading temperature.

1.5.2 The Administration may allow Type C tanks to be loaded according to the formula in *Pt 11, Ch 15, 1.5 Maximum loading limit 1.5.1* with the relative density ρ_R as defined below, provided that the tank vent system has been approved in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.19*.

ρ_R = relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during storage, or at unloading, under the ambient design temperature conditions described in *Pt 11, Ch 15, 1.1 Definitions 1.1.4*.

1.6 Information to be provided to the Operator

1.6.1 A document shall be provided to the unit specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. The information in this document shall be approved by LR.

1.6.2 Pressures at which the PRVs have been set shall also be stated in the document.

1.6.3 A copy of the above document shall be permanently kept onboard by the Operator.

■ *Section 1* General

1.1 Application

1.1.1 Except as provided for in *Pt 11, Ch 16, 5 Alternative fuels and technologies*, Methane (LNG) is the only cargo whose vapour or boil off gas may be utilised in machinery spaces of category A, and in these spaces it may be utilised only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units (GCU) and gas turbines.

1.1.2 In addition to the requirements of this Chapter in respect of using LNG as a fuel, the requirements of Pt 5, Ch 15 are also to be complied with.

1.1.3 The following plans are to be submitted for consideration:

- General arrangement of plan.
- Gas piping systems, together with details of interlocking and safety devices.
- Gas heaters.
- Gas compressors and their prime movers.
- Gas storage pressure vessels.
- Gas and fuel oil burning arrangements.

1.2 Use of cargo vapour as fuel

1.2.1 This section addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, GCUs and gas turbines.

1.2.2 For vaporised LNG, the fuel supply system shall comply with the requirements of *Pt 11, Ch 16, 2.1 Supply requirements 2.1.1*, *Pt 11, Ch 16, 2.1 Supply requirements 2.1.2* and *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3*.

1.2.3 For vaporised LNG, gas consumers shall exhibit no visible flame and shall maintain the uptake exhaust temperature below 535°C.

1.3 Arrangement of spaces containing gas consumers

1.3.1 Spaces in which gas consumers are located shall be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources. The ventilation system shall be separated from those serving other spaces.

1.3.2 Gas detectors shall be fitted in these spaces, particularly where air circulation is reduced. The gas detection system shall comply with the requirements of *Pt 11, Ch 13 Instrumentation and Automation Systems*.

1.3.3 Electrical equipment located in the double wall pipe or duct specified in *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3* shall comply with the requirements of *Pt 11, Ch 10 Electrical Installations*.

1.3.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space and be fitted with a flame screen.

■ *Section 2*
Fuel gas supply

2.1 Supply requirements

2.1.1 General

(a) The requirements of *Pt 11, Ch 16, 2 Fuel gas supply* apply to fuel gas supply piping outside of the cargo area. Fuel piping shall not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routeing of the pipeline shall take into account potential hazards due to mechanical damage, such as stores or machinery handling areas. Provision shall be made for inerting and gas-freeing that portion of the gas fuel piping systems located in the machinery space.

2.1.2 Leak detection

(a) Continuous monitoring and alarms shall be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant gas fuel supply.

2.1.3 Routeing of fuel supply pipes

(a) Fuel piping may pass through or extend into enclosed spaces other than those mentioned in *Pt 11, Ch 16, 1.3 Arrangement of spaces containing gas consumers 1.3.1*, provided it fulfils one of the following conditions:

(i) A double wall design with the space between the concentric pipes pressurised with inert gas at a pressure greater than the gas fuel pressure. The isolating valve, as required by *Pt 11, Ch 16, 2.1 Supply requirements 2.1.5*, closes automatically upon loss of inert gas pressure; or

(ii) Installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, and shall be arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation shall be in accordance with *Pt 11, Ch 12 Artificial Ventilation in the Cargo Area* as applicable. The ventilation shall always be in operation when there is fuel in the piping and the isolating valve, as required by *Pt 11, Ch 16, 2.1 Supply requirements 2.1.5*, shall close automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space, the ventilation outlet shall be in a safe location.

2.1.4 Requirements for fuel gas with pressure greater than 1 MPa

(a) Fuel delivery lines between the high pressure fuel pumps/compressor and consumers shall be protected with a double walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single walled pipe in the cargo area up to the isolating valve(s) required by *Pt 11, Ch 16, 2.2 Spaces containing gas consumers 2.2.1* is acceptable.

(b) The arrangement in *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3* (a) may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of *Pt 11, Ch 16, 2.2 Spaces containing gas consumers 2.2.3* and taking into account the effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.

2.1.5 Gas consumer isolation

(a) The supply piping of each fuel gas consumer unit shall be provided with fuel gas isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves shall be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one shall not affect the fuel gas supply to the others.

2.2 Spaces containing gas consumers

2.2.1 Piping aspects

(a) If the double barrier around the fuel gas supply system is not continuous due to air inlets or other openings, or if there is any point where single failure will cause leakage into the space, it shall be possible to isolate the fuel gas supply to each individual space with an individual master gas fuel valve, which shall be located within the cargo area. It shall operate under the following circumstances:

(i) Automatically by

- Gas detection within the space;
- Leak detection in the annular space of a double walled pipe;
- Leak detection in other compartments inside the space, containing single walled gas piping;
- Loss of ventilation in the annular space of the double walled pipe;
- Loss of ventilation in other compartments inside the space, containing single walled gas piping;

(ii) Manually from within the space, and at least one remote location.

The isolation of fuel gas supply to a space, shall not affect the fuel gas supply to other spaces containing gas consumers and shall not cause loss of propulsion or electrical power.

(b) If the double barrier around the fuel gas supply system is continuous, an individual master valve located in the cargo area may be provided for each gas consumer inside the space. The individual master valve shall operate under the following circumstances:

(i) Automatically by:

- Leak detection in the annular space of a double walled pipe served by that individual master valve;
- Leak detection in other compartments containing single-walled gas piping that is part of the supply system served by that individual master valve;
- Loss of ventilation or loss of pressure in the annular space of a double walled pipe;

(ii) Manually from within the space, and at least one remote location.

(c) It shall be possible to isolate the fuel gas supply to each individual space containing a gas consumer(s) with an individual master gas fuel valve, which is located within the cargo area. It shall operate under the following circumstances:

(i) Automatically by:

- Gas detection within the space;
- Leak detection in the annular space of a double walled space;
- Loss of ventilation in the annular space of the double walled pipe;

(ii) Manually from within the space, and at least one remote location.

(d) The isolation of fuel gas supply to a space shall not affect the gas supply to other spaces containing gas consumers.

2.2.2 **Piping and ducting construction**

(a) Fuel gas piping in machinery spaces shall comply with *Pt 11, Ch 5, 1 General* to *Pt 11, Ch 5, 4.2 Welding, post-weld heat treatment and non-destructive testing* as applicable. The piping shall, as far as practicable, have welded joints. Those parts of the fuel gas piping that are not enclosed in a ventilated pipe or duct according to *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3*, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be fully radiographed.

(b) The fuel gas piping in the machinery space is to be tested in place by hydraulic pressure to 7 bar or twice the working pressure, whichever is the greater. Subsequently, the lines are to be tested by air at the working pressure using soapy water, or equivalent, to verify that all joints are absolutely tight.

2.2.3 **Gas detection**

(a) Gas detection systems provided in accordance with the requirements of this chapter shall activate the alarm at a relatively low per cent LFL (typically 20 per cent of the LFL in air) and shut down the master fuel gas valve required by *Pt 11, Ch 16, 2.2 Spaces containing gas consumers*. at not more than 60 per cent LFL. *See also Pt 11, Ch 16, 2.1 Supply requirements 2.1.5*.

■ *Section 3*
Fuel gas plant and related storage tanks

3.1 Provision of fuel gas

3.1.1 All equipment (heaters, compressors, vaporisers, filters, etc.) for conditioning the cargo and/or cargo boil off vapour for its use as fuel, and any related storage tanks, shall be located in the cargo or topside areas. If the equipment is located in an enclosed space the space shall be ventilated according to *Pt 11, Ch 12, 1.1 Spaces required to be entered during normal cargo handling operations*, be equipped with a fixed fire-extinguishing system, according to *Pt 11, Ch 11, 1.5 Enclosed spaces*

containing cargo handling equipment, and with a gas detection system according to *Pt 11, Ch 13, 1.6 Gas detection*, as applicable.

3.1.2 Provision is to be made to enable the machinery and associated pipework used for preparing and supplying the gas boil-off to be purged of flammable gas prior to being opened up for maintenance or survey.

3.1.3 Gas heaters and compressors, of watertight construction, may be installed on the open deck provided they are suitably located and protected from mechanical damage.

3.1.4 The prime movers for the gas compressors are to be regulated to maintain a positive suction pressure and arranged to stop automatically if the pressure on the suction side of the compressors is lower than 0,035 bar gauge or other approved positive pressure appropriate to the cargo tank system.

3.1.5 The suction and discharge connections to the compressors are to be fitted with isolating valves.

3.2 Remote stops

3.2.1 All rotating equipment utilised for conditioning the cargo for its use as fuel shall be arranged for manual remote stop from the engine room. Additional remote stops shall be located in areas that are always easily accessible, typically cargo control room, navigation bridge where applicable and fire control station.

3.2.2 The fuel supply equipment shall be automatically stopped in the case of low suction pressure or fire detection. The requirements of *Pt 11, Ch 18, 4.1 General 4.1.1* need not apply to fuel gas compressors or pumps when used to supply gas consumers.

3.3 Heating and cooling mediums

3.3.1 If the heating or cooling medium for the fuel gas conditioning system is returned to spaces outside the cargo area, provisions shall be made to detect and alarm the presence of cargo/cargo vapour in the medium. Any vent outlet shall be in a safe position and fitted with an effective flame screen of an approved type.

3.4 Piping and pressure vessels

3.4.1 Piping or pressure vessels fitted in the fuel gas supply system shall comply with *Pt 11, Ch 5 Process Pressure Vessels and Liquids, Vapour and Pressure Piping Systems and Offshore Arrangements*.

3.4.2 Pressure vessels for storing methane gas are to be of approved design and fitted with pressure relief valves discharging to atmosphere in a safe position.

■ *Section 4*
Gas consummers

4.1 Special requirements for main boilers

4.1.1 **Arrangements**

(a) Each boiler shall have a separate exhaust uptake.
(b) Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.
(c) Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

4.1.2 **Combustion equipment**

(a) The burner systems should be of dual type suitable to burn either:

- fuel oil.
- gas fuel.
- oil and gas fuel simultaneously.

(b) Burners shall be designed to maintain stable combustion under all firing conditions.
(c) In the event of loss of fuel gas supply an automatic system shall be fitted to change over from fuel gas operation to fuel oil operation without interruption of the boiler firing.

(d) Gas nozzles and the burner control system shall be configured such that fuel gas can only be ignited by an established fuel oil flame, unless the boiler and combustion equipment is designed and approved by LR to light on fuel gas.

(e) Fuel oil alone is to be used for starting up. It should be possible to change over easily and quickly from gas to fuel oil operation. These requirements should apply unless otherwise agreed by the Administration. Each boiler is to have a separate uptake to the top of the funnel or a separate funnel.

(f) The firing equipment is to be of combined gas and oil type and be capable of burning both fuels simultaneously. The gas nozzles are to be so disposed as to obtain ignition from the oil flame. An interlocking device is to be provided to prevent the gas fuel supply being opened until the oil and air controls are in the firing position.

4.1.3 **Safety**

(a) There shall be arrangements to ensure that fuel gas flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

(b) On the pipe of each gas burner a manually operated shut-off valve shall be fitted.

(c) Provisions shall be made for automatically purging the fuel gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

(d) The automatic fuel changeover system required by *Pt 11, Ch 16, 4.1 Special requirements for main boilers 4.1.2* (c) shall be monitored with alarms to ensure continuous availability.

(e) Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

(f) Arrangements shall be made to enable the boilers to be manually purged.

(g) An inert gas or steam purging connection is to be provided on the burner side of the shut-off arrangements so that the pipes to the gas nozzles can be purged immediately before and after methane gas is used for firing purposes.

(h) Each burner supply pipe is to be fitted with a gas shut-off cock and a flame arrester unless this is incorporated in the burner. An audible alarm is to be provided giving warning of loss of minimum effective pressure in the fuel oil discharge line or failure of the fuel pump.

(i) In addition to the low water level fuel shutoff and alarm required by *Pt 5, Ch 10, 15.7 Low water level fuel shut-off and alarm* or *Pt 5, Ch 10, 16.7 Low water level fuel shut-off and alarm* of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) for oil-fired boilers, similar arrangements are to be made for gas shut-off and alarms when the boilers are being gas-fired.

(j) A notice board is to be provided at the firing platform stating:

'If ignition is lost from both oil and gas burners, the combustion spaces are to be thoroughly purged of all combustible gases before relighting the oil burners'.

4.2 Special requirements for gas-fired internal combustion engines

4.2.1 **General**

(a) In addition to the requirements for gas-fired internal combustion engines outlined in this Chapter, the requirements of *Pt 5, Ch 2 Engines* are to be complied with.

(b) Dual fuel engines are those that employ fuel gas (with pilot oil) and fuel oil. Fuel oils may include distillate and residual fuels. Gas only engines are those that employ fuel gas only.

4.2.2 **Arrangements**

(a) When fuel gas is supplied in a mixture with air through a common manifold, flame arrestors shall be installed before each cylinder head.

(b) Each engine shall have its own separate exhaust.

(c) The exhausts shall be configured to prevent any accumulation of unburnt gaseous fuel.

(d) Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, then air inlet manifolds, scavenge spaces, exhaust system and crank cases shall be fitted with suitable pressure relief systems. Pressure relief systems shall lead to a safe location, away from personnel.

(e) Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

4.2.3 **Combustion equipment**

(a) Prior to admission of fuel gas, correct operation of the pilot oil injection system on each unit shall be verified.

(b) For a spark ignition engine, if ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, this shall be automatically shut off and the starting sequence terminated. It shall be ensured that any unburned gas mixture is purged from the exhaust system.
(c) For dual fuel engines fitted with a pilot oil injection system an automatic system shall be fitted to change over from fuel gas operation to fuel oil operation with minimum fluctuation of the engine power.
(d) In the case of unstable operation on engines with the arrangement in (c) when gas firing, the engine shall automatically change to fuel oil mode.

4.2.4 **Safety**

(a) During stopping of the engine the gas fuel shall be automatically shut off before the ignition source.
(b) Arrangements shall be provided to ensure that there is no unburnt fuel gas in the exhaust gas system prior to ignition.
(c) Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection. *See Pt 11, Ch 13, 1.6 Gas detection 1.6.17*.
(d) Provision shall be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase shall be in accordance with the requirements of *Pt 11, Ch 10 Electrical Installations*.
(e) A means shall be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of *Pt 11, Ch 10 Electrical Installations*.

4.2.5 **Additional requirements for gas-fired internal combustion engines and gas turbines**

(a) Main engines are to be of the dual-fuel type capable of immediate changeover to fuel oil only. All starting is to be carried out on fuel oil alone.
(b) Each cylinder is to be provided with its own individual gas inlet valve admitting gas either to the cylinder or to air inlet port. The timing of this valve is to be such that no gas can pass to the exhaust during the scavenge period nor to the inlet port after closure of the air inlet valve.
(c) In the event of a fault in the timing mechanism or a cylinder misfire, the exhaust, scavenge and air inlet manifolds are to be protected against the effect of an explosion. Where explosion relief valves are fitted they are to relieve to a safe location.
(d) An isolating valve and flame arrester is to be provided at the inlet to the gas supply manifold for each engine. The isolating valve is to be arranged to close automatically in the event of low gas pressure, or failure of any cylinder to fire. Arrangements are to be made so that the gas supply to each engine can be shut off manually from the control position.
(e) The crankcase is to be fitted with gas detecting, or equivalent, equipment, and a means for the injection of inert gas. The inert gas injection is to be capable of remote operation from a safe location.

Crankcase relief valves are also to be fitted as required by *Pt 5, Ch 2,6* of the Rules for Ships.

4.3 Special requirements for gas turbines

4.3.1 **General**

(a) In addition to the requirements for gas turbines outlined in this Chapter, the requirements of *Pt 5, Ch 3 Steam Turbines* are to be complied with.

4.3.2 **Arrangements**

(a) Gas turbines are also to comply with *Pt 11, Ch 16, 4.2 Special requirements for gas-fired internal combustion engines 4.2.5*.
(b) Each turbine shall have its own separate exhaust.
(c) The exhausts shall be appropriately configured to prevent any accumulation of unburnt gas fuel.
(d) Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a non-hazardous location, away from personnel.

4.3.3 **Combustion equipment**

(a) An automatic system shall be fitted to change over easily and quickly from fuel gas operation to fuel oil operation with minimum fluctuation of the engine power.

4.3.4 **Safety**

(a) Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply shall be shut down.

(b) Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

■ *Section 5* Alternative fuels and technologies

5.1 Fuels other than LNG

5.1.1 If acceptable to the Administration, other cargo gases may be used as fuel providing that the same level of safety as natural gas in this Part is ensured.

The use of cargoes identified as toxic by the IGC Code shall not be permitted.

5.1.2 For cargoes other than LNG, the fuel supply system shall comply with the requirements of *Pt 11, Ch 16, 2.1 Supply requirements 2.1.1*, *Pt 11, Ch 16, 2.1 Supply requirements 2.1.2*, *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3* and *Pt 11, Ch 16, 3 Fuel gas plant and related storage tanks*, as applicable, and shall include means for preventing condensation of vapour in the system.

5.1.3 Liquefied fuel gas supply systems shall comply with *Pt 11, Ch 16, 2.1 Supply requirements 2.1.5*.

5.1.4 In addition to the requirements of *Pt 11, Ch 16, 2.1 Supply requirements 2.1.3* (a)(ii), both ventilation inlet and outlet shall be in a non-hazardous area external to the machinery space.

■ *Section 6* Survey

6.1 Applicability

6.1.1 The gas compressors, heaters, pressure vessels and piping are to be constructed under Special Survey, and the installation of the whole plant on board the ship unit is to be carried out under the supervision of Lloyd’s Register’s (LR) Surveyors. On completion, the installation is to be tested to prove its capability.

Section
1 Special Requirements

Section 1
Special Requirements

1.1 General

The provisions of this Chapter are applicable where reference is made in column 'i' in the *Table 19.1.2 Explanatory notes to the summary of minimum requirements*.

1.2 Flame screens on vent outlets

When carrying a cargo referenced to this Section, cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type. Due attention shall be paid to the design of flame screens and vent heads, to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Flame screens shall be removed and replaced by protection screens in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.16* when carrying cargoes not referenced to this Section.

1.3 Cargo pumps and discharge arrangements

1.3.1 The vapour space of cargo tanks equipped with submerged electric motor pumps shall be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

1.3.2 The cargo shall be discharged only by deepwell pumps or by hydraulically operated submerged pumps. These pumps shall be of a type designed to avoid liquid pressure against the shaft gland.

1.3.3 Inert gas displacement may be used for discharging cargo from Type C independent tanks provided the cargo system is designed for the expected pressure.

1.4 Carbon dioxide – High purity

1.4.1 Uncontrolled pressure loss from the cargo can cause 'sublimation' and the cargo will change from the liquid to the solid state. The precise 'triple point' temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this Section shall be set to at least 0,05 MPa above the triple point for the specific cargo being carried. The 'triple point' for pure carbon dioxide occurs at 0,05 MPa and –54,4°C.

1.4.2 There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems*, fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.10* (b) of this Part do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping so the requirements of *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.16* of this Part do not apply.

1.4.3 Discharge piping from safety relief valves are not required to comply with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.11*, but shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping so the requirements of *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.16* of this Part do not apply.

1.4.4 Cargo tanks shall be continuously monitoring for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0,05 MPa of the 'triple point' for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown system required by *Pt 11, Ch 18, 4 Linked emergency shutdown (ESD) system* of this Part may be used for this purpose.

1.4.5 All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in *Pt 11, Ch 17, 1.4 Carbon dioxide – High purity 1.4.1*.

1.4.6 Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of *Pt 11, Ch 13, 1.6 Gas detection* of this Part, and hold spaces shall be monitored permanently even if the ship unit has Type C cargo containment.

1.5 Carbon dioxide – Reclaimed quality

1.5.1 The requirements of *Pt 11, Ch 17, 1.4 Carbon dioxide – High purity* also apply to this cargo. In addition, the materials of construction used in the cargo system shall also take account of the possibility of corrosion in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc. which can cause acidic corrosion or other problems.

1.6 Nitrogen

1.6.1 Materials of construction and ancillary equipment such as insulation shall be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration shall be given to venitilation in such areas, where condensation might occur, to avoid the stratification of oxygen-enriched atmosphere.

■ *Section 1* General

1.1 Personnel

1.1.1 Those involved in liquefied gas operations are to be made aware of the special requirements associated with, and precautions necessary for, their safe operation.

1.2 Cargo operations manuals

1.2.1 The ship unit shall be provided with copies of suitably detailed cargo system operating manuals approved by the Administration such that trained personnel can safely operate the unit with due regard to the hazards and properties of the cargoes that are permitted to be carried.

1.2.2 The content of the manuals shall include but not be limited to:

(a) Overall operation of the ship unit including procedures for cargo tank cool-down and warm-up, cargo transfer, cargo sampling, gas freeing, ballasting, tank cleaning and changing cargoes;
(b) cargo temperature and pressure control systems;
(c) cargo system limitations, including minimum temperatures (cargo system and inner hull), maximum pressures, cargo transfer rates and filling limits;
(d) nitrogen and inert gas systems;
(e) fire-fighting procedures: operation and maintenance of fire-fighting systems and use of extinguishing agents;
(f) special equipment needed for the safe handling of the particular cargo;
(g) fixed and portable gas detection;
(h) control, alarm and safety systems;
(i) emergency shut-down systems;
(j) procedures to change cargo tank pressure relief valve set pressures in accordance with *Pt 11, Ch 8, 1.2 Pressure relief systems 1.2.9* and *Pt 11, Ch 4, 3.3 Functional loads 3.3.2* (c);
(k) emergency procedures, including cargo tank relief valve isolation, single tank gas-freeing and entry.

1.3 Cargo information

1.3.1 Information shall be on board and available to all concerned in the form of a cargo information data sheet(s) giving the necessary data for safe cargo operation. Such information shall include, for each product carried:

(a) a full description of the physical and chemical properties necessary for safe cargo operations and containment of the cargo;
(b) reactivity with other cargoes that are capable of being stored.
(c) the actions to be taken in the event of cargo spills or leaks.
(d) countermeasures against accidental personal contact.
(e) fire-fighting procedures and fire-fighting media.
(f) special equipment needed for the safe handling of the particular cargo.
(g) emergency procedures.

1.3.2 The physical data supplied to the Operator, in accordance with *Pt 11, Ch 18, 1.3 Cargo information 1.3.1* (a), shall include information regarding the relative cargo density at various temperatures to enable the calculation of cargo tank filling limits in accordance with the requirements of *Pt 11, Ch 15 Filling Limits for Cargo Tanks*.

1.3.3 Contingency plans in accordance with *Pt 11, Ch 18, 1.3 Cargo information 1.3.1* (c), for spillage of cargo carried at ambient temperature, shall take account of potential local temperature reduction such as when the escaped cargo has reduced to atmospheric pressure and the potential effect of this cooling on hull steel.

■ *Section 2*
Storage and transfer

2.1 Product suitability

2.1.1 The Operator shall ascertain that the quantity and characteristics of each product to be loaded are within the limits indicated in the Loading and Stability Information booklet provided for in *Pt 11, Ch 2, 1.2 Freeboard and stability 1.2.5*.

2.1.2 Care should be taken to avoid dangerous chemical reactions if cargoes are mixed. This is of particular significance in respect of:

(a) tank cleaning procedures required between successive cargoes in the same tank; and
(b) simultaneous storage of cargoes that react when mixed. This shall be permitted only if the complete cargo systems including, but not limited to, cargo pipework, tanks, vent systems and refrigeration systems, are separated as defined in *Pt 11, Ch 1, 1.3 Definitions 1.3.1* (as).

2.2 Storage of cargo at low temperature

2.2.1 When carrying cargoes at low temperatures:

(a) the cool-down procedure laid down for that particular tank, piping and ancillary equipment shall be followed closely.
(b) loading shall be carried out in such a manner as to ensure that cargo design temperature gradients are not exceeded in any cargo tank, piping or other ancillary equipment.
(c) if provided, the heating arrangements associated with the cargo containment systems shall be operated in such a manner as to ensure that the temperature of the hull structure does not fall below that for which the material is designed.

2.3 Cargo transfer operations

2.3.1 A pre cargo operations meeting shall take place between shuttle tanker personnel and the persons responsible at the transfer facility of the ship unit. Information exchanged shall include the details of the intended cargo transfer operations and emergency procedures. A recognised industry checklist shall be completed for the intended cargo transfer and effective communications shall be maintained throughout the operation.

2.3.2 Essential cargo handling controls and alarms shall be checked and tested prior to cargo transfer operations.

2.4 Cargo sampling

2.4.1 Any cargo sampling shall be conducted under the supervision of an Officer who shall ensure that protective clothing appropriate to the hazards of the cargo is used by everyone involved in the operation.

2.4.2 When taking liquid cargo samples the Officer shall ensure that the sampling equipment is suitable for the temperatures and pressures involved, including cargo pump discharge pressure if relevant.

2.4.3 The Officer shall ensure that any cargo sample equipment used is connected properly to avoid any cargo leakage.

2.4.4 After sampling operations are completed, the Officer shall ensure that any sample valves used are closed properly and the connections used are correctly blanked.

Section 3
Personnel

3.1 Training

3.1.1 Personnel shall be adequately trained in the operational and safety aspects of the unit. As a minimum:

(a) All personnel shall be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions.

(b) Crew shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo and a sufficient number of them shall be instructed and trained in essential first aid for the cargoes carried.

3.2 Entry into enclosed spaces

3.2.1 Under normal operational circumstances personnel shall not enter cargo tanks, hold spaces, void spaces, or other enclosed spaces where gas may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of toxic atmosphere.

3.2.2 If it is necessary to gas-free and aerate a hold space surrounding a Type A cargo tank for routine inspection, and the cargo tank is carrying flammable cargo, the inspection shall be conducted when the tank contains only the minimum amount of cargo 'heel' to keep the cargo tank cold. The hold shall be re-inerted as soon as the inspection is completed.

3.2.3 Personnel entering any space designated as a hazardous area on a ship unit carrying flammable products shall not introduce any potential source of ignition into the space unless it has been certified gas free and is maintained in that condition. Portable gas detection equipment must be utilised at all times to ensure personnel safety.

Section 4
Linked emergency shutdown (ESD) system

4.1 General

4.1.1 An emergency shutdown (ESD) system shall be fitted to all ship units to stop cargo flow in the event of an emergency, either internally within the ship unit, or during cargo transfer with shuttle tankers. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work, *see Pt 11, Ch 18, 4.2 ESD valve requirements 4.2.1* (d). For linked ESD systems the requirements in *Pt 7, Ch 1, 7.4 Linked ESD systems* are to be satisfied.

4.1.2 Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

4.2 ESD valve requirements

4.2.1 **General**

(a) The term ESD valve means any valve operated by the ESD system.

(b) ESD valves shall be remotely operated, be of the fail closed type (closed on loss of actuating power), shall be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve shall be permitted. The manual valve shall be located adjacent to the ESD valve. Provisions shall be made to handle trapped liquid should the ESD valve close while the manual valve is also closed.

A manually operated vent valve in the pneumatic/hydraulic logic is preferable to an additional in-line valve.

Table 18.4.1 ESD Functional Arrangements

	Pumps		Compressor Systems				Valves	Link
Shut-down action → Initiation ↓	Cargo pumps/ cargo booster pumps	Spray/ stripping pumps	Vapour return compressors	Fuel gas compressors and system	Reliquefaction plant****, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to ship unit-shuttle tanker link *****
Emergency push buttons (*see Pt 11, Ch 18, 4.1 General 4.1.2*)		✓	✓	Note 2	✓	✓	✓	✓
Fire detection on deck or in compressor house*	✓	✓	✓	Note 2	✓	✓	✓	✓
High level in cargo tank***	✓	✓	✓	Note 1 Note 2	Note 1	Note 1	Note 4	✓
Signal from ship unit-shuttle tanker link	✓	✓	✓	Note 2	Note 3	n/a	✓	n/a
Loss of motive power to ESD valves**	✓	✓	✓	Note 2	n/a	n/a	✓	✓
Main electric power failure ('blackout')	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	✓	✓

NOTES

1. These items of equipment can be omitted from these specific automatic shut-down initiators provided the compressor inlets are protected against cargo liquid ingress.

2. If the fuel gas compressor is used to return cargo vapour to the ship unit, it shall be included in the ESD system only when operating in this mode.

3. If the reliquefaction plant compressors are used for vapour return/ship unit line clearing, they shall be included in the ESD system only when operating in that mode.

4. Alternatively, a stage 1 high level in an individual cargo tank may initiate the closure of the shut-off valve referred to in *Pt 11, Ch 13, 1.3 Overflow control 1.3.2*, and not the ESD valve referred to in *Pt 11, Ch 18, 4.2 ESD valve requirements 4.2.1*. The sensor indicated in *Pt 11, Ch 13, 1.3 Overflow control 1.3.2* shall also ensure that when all tank valves referred to in *Pt 11, Ch 13, 1.3 Overflow control 1.3.2* are shut that the ESD in *Pt 11, Ch 18, 4.1 General 4.1.2* is operated.

5. These items of equipment shall not be started automatically upon recovery of main electric power and without confirmation of safe conditions.

Remarks

* Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.

** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.

*** *See Pt 11, Ch 13, 1.3 Overflow control 1.3.2* and *Pt 11, Ch 13, 1.3 Overflow control 1.3.3*.

**** Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

***** Signal need not indicate the event initiating ESD.

✓ Functional requirement.

n/a Not applicable.

(c) ESD valves in liquid piping systems shall close fully and smoothly within 30 seconds of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

(d) The closing time of the valve referred to in *Pt 11, Ch 13, 1.3 Overflow control 1.3.1* to *Pt 11, Ch 13, 1.3 Overflow control 1.3.3* (i.e. time from shut-down signal initiation to complete valve closure) shall not be greater than:

$$\frac{3600U}{LR}$$

where

U = ullage volume at operating signal level (m^3)

LR = maximum loading rate agreed between ship unit and shuttle tanker (m^3/h).

The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm and the piping systems of the ship unit and shuttle tanker where relevant.

4.2.2 **Ship unit-shuttle tanker manifold connections**

(a) One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

4.2.3 **Cargo system valves**

(a) If cargo system valves as defined in *Pt 11, Ch 5, 2.2 Cargo system valve requirements* are also ESD valves within the meaning of this section, then the requirements of this section will apply.

4.2.4 **ESD system controls**

(a) As a minimum, the ESD system shall be capable of manual operation by a single control in the control position required by *Pt 11, Ch 13, 1.1 General 1.1.2* or the cargo control room if installed, and no less than two locations in the cargo area.

(b) The ESD shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks should cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly.

(c) The ESD system shall be activated by the manual and automatic inputs listed in *Table 18.4.1 ESD Functional Arrangements*. Any additional inputs should only be included in the ESD system if it can be shown their inclusion does not reduce the integrity and reliability of the system overall.

4.2.5 **Additional shut-downs**

(a) The requirements of *Pt 11, Ch 8, 1.3 Vacuum protection systems 1.3.1* (a) to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or as a minimum to stop any cargo pumps or compressors.

(b) An input to the ESD system from the overflow control system required by *Pt 11, Ch 13, 1.3 Overflow control* may be provided to stop any cargo pumps or compressors running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.

4.2.6 **Pre-operations testing**

(a) Cargo emergency shut-down and alarm systems involved in cargo transfer shall be checked and tested before cargo handling operations begin.

■ *Section 5*
Other aspects

5.1 Hot work on or near cargo containment systems

5.1.1 Special fire precautions shall be taken in the vicinity of cargo tanks and particularly insulation systems that may be flammable or contaminated with hydrocarbons or that may give off toxic fumes as a product of combustion.

5.2 Additional operating requirements

5.2.1 Additional operating requirements will be found in the following paragraphs of this Part

Ch 2, 1.2.2, 1.2.5, 1.2.6
Ch 3 1.8.3, 1.8.4
Ch 5 1.3.2(a)(i), 1.3.3(a)(iii), 3.1.3,
Ch 7 1.1.
Ch 8, 1.2.8, 1.2.9, 1.2.10
Ch 9, 1.2, 1.3, 1.4.4
Ch 12, 1.1.1
Ch 13, 1.1.3, 1.3.5, 1.6.18
Ch 14, 1.3.3
Ch 15, 1.3, 1.6
Ch 16, 4.1.3

Section
1 Summary of Minimum Requirements

Section 1
Summary of Minimum Requirements

1.1 Explanatory notes to the summary of minimum requirements

Table 19.1.1 Explanatory notes to the summary of minimum requirements

Product name (column a)	
UN Number (column b)	
Ship type (column c)	Ship unit type 2G, *see Pt 11, Ch 2 Ship Survival Capability and Location of Cargo Tanks*
Independent tank type C required (column d)	– not required under the IGC Code
Tank environmental control (column e)	– no special requirements under the IGC Code
Vapour detection (column f)	F: Flammable vapour detection A: Asphixiant
Gauging (column g)	R: Indirect, closed or restricted, *see Pt 11, Ch 13 Instrumentation and Automation Systems* C: indirect or closed, *see Pt 11, Ch 13 Instrumentation and Automation Systems*
MFAG Table no. (column h)	MFAG numbers are provided for information on the emergency procedures to be applied in the event of an accident involving the products covered by the IGC Code Where any of the products listed are carried at low temperature from which frostbite may occur, MFAG no. 620 is also applicable
Special requirements (column i)	When specific reference is made to *Pt 11, Ch 17 Special Requirements*, these requirements shall be additional to the requirements in any other column

Table 19.1.2 Explanatory notes to the summary of minimum requirements

a	b	c	d	e	f	g	h	I
Product name	UN number	Ship unit type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	MFAG Table no.	Special requirements
Butane	1011	2G	—	—	F	R	310	—
Butane-propane mixture	1011/1978	2G	—	—	F	R	310	—
Carbon dioxide (High Purity)	—	2G *see* Note 1	—	—	A	R	—	*Pt 11, Ch 17, 1.4 Carbon dioxide – High purity*

Carbon dioxide (Reclaimed Quality)	—	2G *see* Note 1	—	—	A	R	—	*Pt 11, Ch 17, 1.5 Carbon dioxide – Reclaimed quality*
Ethane	1961	2G	—	—	F	R	310	—
Methane (LNG)	1972	2G	—	—	F	C	620	—
Nitrogen	2040	2G *see* Note 1	—	—	A	C	—	*Pt 11, Ch 17, 1.6 Nitrogen*
Pentane (all isomers) *see* Note 2	1265	2G	—	—	F	R	310	*Pt 11, Ch 17, 1.2 Flame screens on vent outlets*, *Pt 11, Ch 17, 1.3 Cargo pumps and discharge arrangements 1.3.1*
Propane	1978	2G	—	—	F	R	310	—

LR NOTES

1. Ship units designed to store LNG or LPG with additional tanks to store carbon dioxide are to comply with the requirements for ship unit type 2G.

2. This cargo is also covered by the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code).

Barges and Offshore Units Equipped with Regasification

Section

■ *Section 1* General

1.1 Goal

1.1.1 The goal of the Rules contained in this Section is to provide for the safe regasification of liquefied natural gas (LNG), minimising the risk to the barge or offshore unit, its crew and to the environment by specifying requirements for the design, construction and installation of regasification systems on board barges or offshore units having regard to the nature of the products including; flammability, toxicity, asphyxiation, corrosivity, reactivity, temperature and pressure.

1.2 Application

1.2.1 The requirements of these Rules apply to barges and offshore units that are equipped with regasification systems and associated sub-systems.

1.2.2 Dependent on the barge or offshore unit service and regasification operational location, requirements additional to these Rules may be imposed by the National Authority with whom the barge or offshore unit is registered and/or by the Administration within whose territorial jurisdiction the barge or offshore unit is intended to operate.

1.2.3 The Rules do not repeat the general requirements for fire safety as stated in statutory conventions. These Rules do, however, include fire safety requirements additional to those stated in the statutory conventions that are specific to the construction and equipment of regasification systems.

1.2.4 Unless requested, classification will not include those systems which are additional to the regasification, heating and 'send-out' process equipment such as; blending facilities, odorizers, or dew point correction/dehumidification, except where the design and/or arrangements of such equipment and piping may affect the safety of the vessel.

1.3 Class notation

1.3.1 The following notations may be assigned as considered appropriate by the Classification Committee, on application from the Owners:

✠ **Lloyd's RGP** – This notation will be assigned when a regasification system and arrangements have been constructed, installed and tested under Lloyd's Register's (hereinafter referred to as LR's) Special Survey and in accordance with the relevant requirements of the Rules.

✠ **Lloyd's RGP+** – This notation will be assigned when a regasification system and arrangements have been constructed, installed and tested under LR's Special Survey and in accordance with the relevant requirements of the Rules and the system is configured to allow continuing operation in the event of a single failure.

1.4 Survey

1.4.1 The regasification plant and its sub-systems and equipment shall be installed and tested to the Surveyor's satisfaction.

1.4.2 All regasification plant and sub-systems shall be subject to the following surveys:

(a) an Initial Survey before the regasification system is put into service, which should include a complete examination of its structure, equipment, fittings, arrangements and materials of the regasification system. This survey should be such as to ensure that the structure, equipment, fittings, arrangements and material fully comply with the applicable provisions of these Rules;

(b) a Complete Survey at intervals specified by the LR, but not exceeding 5 years. The Complete Survey should be such as to ensure that the structure, equipment, fittings, arrangements and material fully comply with the applicable provisions of these Rules and are in good working order;

(c) an Intermediate Survey within 3 months before or after the second anniversary date or within 3 months before or after the third anniversary date of the Certificate which should take the place of one of the annual surveys specified in *Pt 11, Ch 20, 1.4 Survey 1.4.2* (d). The Intermediate Survey should be such as to ensure that the safety equipment, and other equipment, and associated pump and piping systems fully comply with the applicable provisions of these Rules and are in good working order;

(d) an Annual Survey within 3 months before or after each anniversary date of the Certificate, including a general inspection of the structure, equipment, fittings, arrangements and material of the regasification system to ensure that they have been maintained in accordance with *Pt 11, Ch 20, 1.4 Survey 1.4.6*, and that they remain satisfactory for the service for which the barge or offshore unit is intended;

(e) an additional survey, either general or partial according to the circumstances, should be carried out when required after an investigation prescribed in *Pt 11, Ch 20, 1.4 Survey 1.4.8*, or whenever any significant repairs or renewals are made. Such a survey should ensure that the necessary repairs or renewals have been effectively made, that the material and workmanship of such repairs or renewals are satisfactory, and that the regasification unit remains in accordance with the requirements of these Rules and other relevant standards.

1.4.3 Surveys referred to in *Pt 11, Ch 20, 1.4 Survey 1.4.2* are to be in accordance with *Pt 1, Ch 3, 6 Machinery Surveys – General requirements*, *Pt 1, Ch 3, 9 Electrical equipment*, *Pt 1, Ch 3, 14 Process plant facility*, *Pt 1, Ch 3, 17 Pressure vessels for process and drilling plant* and *Pt 1, Ch 3, 18 Inert gas systems*, as applicable.

1.4.4 In addition to the survey and certification of equipment required by relevant Sections of these Rules, the major items of equipment included in the regasification system are required to be constructed under survey at the manufacturer's works. These include, but are not limited to, vaporisers, heat exchangers and their circulating pumps, LNG booster pumps and gas compressors.

1.4.5 Where the ✠ **Lloyd's RGP+** notation is assigned, the means of providing continuing operation in the event of a single failure, as demonstrated in the dependability assessment, see *Pt 11, Ch 20, 3.3 System dependability*, is to be examined and tested as part of the commissioning trials, see *Pt 11, Ch 20, 8.2 Commissioning regasification trials*, to ascertain that the system will continue to operate.

1.4.6 The condition of the regasification system shall be maintained in accordance with the provisions of these Rules to ensure that the system remains fit to operate without danger to the barge, offshore unit or persons and without presenting unreasonable threat of harm to the marine environment.

1.4.7 After any survey of the regasification system has been completed, no change should be made in the structure, equipment, fittings, arrangements and material covered by the survey, without the sanction of LR, except by direct replacement.

1.4.8 Wherever an accident occurs to a regasification system or a defect is discovered, either of which affects the safety of the barge, offshore unit or regasification system, the efficiency or completeness of its life-saving appliances or other equipment covered by these Rules, the Operator or Owner of the barge or offshore unit should report at the earliest opportunity to LR, who should cause investigations to be initiated to determine whether a survey, as required by *Pt 11, Ch 20, 1.4 Survey 1.4.2* (e), is necessary.

1.4.9 Unless they form part of the classed equipment, surveys will not include those systems which are additional to the send-out process plant equipment, such as blending facilities, odorizers, dew point correction/dehumidification, except where the design and/or arrangements of such equipment and piping may affect the safety of the barge or offshore unit.

1.5 Definition

1.5.1 **Area** means a defined location. An area can be on open deck. An area can be open, semi-enclosed or enclosed. An area can be a space below deck. An area can be hazardous or none-hazardous.

1.5.2 **Blowdown** is defined as the depressurisation of a system, part of a system and its equipment to allow the safe disposal of both vapour and liquid discharged from blowdown valves. Depressurisation is used to mitigate the consequences of a pipeline or vessel leak by reducing the leakage rate and/or inventory within the pipe or vessel prior to a potential failure.

1.5.3 **Dependability** is as defined in IEC 60050(191): Quality vocabulary – Part 3: *Availability, reliability and maintainability terms – Section 3.2: Glossary of international terms*. It is the collective term used to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance and relates to essential services as agreed with LR. Note: Dependability is used only for general descriptions in non-quantitative terms.

1.5.4 **Enclosed space** is any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally. In practical terms, this is a space bounded either on all sides, or all but one side, by bulkheads and decks irrespective of openings, such that the required ventilation rate to prevent the accumulation of pockets of stagnant air cannot be achieved by natural ventilation alone.

1.5.5 **Essential services** are:

- those systems, sub-systems and equipment required to provide continued safe operation of the regasification system; and as defined by *Pt 6, Ch 2, 1.6 Definitions 1.6.2*.

1.5.6 **Gasification** is the process of heating a saturated vapour (NG) by the addition of heat from an external source, above its saturation temperature.

1.5.7 '**Gas Safe Space**' is a space that lies wholly outside a gas dangerous space or zone or is one that is engineered as a gas safe place within certain gas dangerous spaces or zones as required in these Rules.

1.5.8 **Hazardous area** is as defined in IEC 60079-10-1: *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*.

1.5.9 **High pressure** refers to systems, equipment and components containing LNG with a design pressure greater than 10 bar g.

1.5.10 **Novel design:** designs of machinery and engineering systems that are considered by LR to be unconventional.

1.5.11 A **Reasonably foreseeable abnormal condition** is an event, incident or failure that:

- has happened and could happen again;
- Is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

1.5.12 **Regasification System** is the complete gasification process plant from LNG storage tanks to the gas export (send-out) shore connection including regasification unit, suction drum, associated pumping, piping and sub-systems.

1.5.13 **Regasification Unit** is referring to vaporisers, heaters, LNG booster pump and associated piping intended for the gasification of LNG from the storage tanks.

1.5.14 **Risk assessment** is the evaluation of likelihood and consequence together with a judgement on the significance of the result, see IEC/ISO 31010: *Risk management, risk assessment techniques*.

1.5.15 **Risk:** the combination of the likelihood of an event and its consequence. Likelihood may be expressed as a probability or a frequency.

1.5.16 **Send-out** is the discharge of the high pressure gas after the vaporisation and heating process. Send-out may include additional processes, such as trim heating, calorific correction, odorization, or dew point correction/ dehumidification.

1.5.17 **Vaporisation** is the controlled boiling of a liquid (in this case LNG) due to the addition of heat from an external source.

1.5.18 **Vent Mast:** Discharges from relief valves and purging systems are carried to the atmosphere through vent masts, the outlets of which are designed to promote vapour dispersal and reduce the risk of flammable mixtures being produced.

1.5.19 Other appropriate definitions as indicated in other Chapters of these Rules and the Rules for Ships.

Section 2
Submission of plans and documentation

2.1 General

2.1.1 Documentation, together with the relevant information as detailed in this Section, shall be submitted for consideration.

2.1.2 Any alterations to basic design, construction, materials, manufacturing procedure, equipment, fittings or arrangements of the process shall be re-submitted for approval before the regasification plant is put into operation.

2.2 Systems and arrangements

2.2.1 The plans and information required by relevant Sections of these Rules are to be submitted for appraisal.

2.2.2 System description document: a description of the arrangements and the intended operating philosophy, design criteria and functionality of the regasification system. It shall include the following information:

(a) Particulars of piping arrangements and control systems, including material specifications, design pressures, design temperatures, ambient design temperatures and control system operational specification;
(b) Operating design criteria that may include, as applicable:
  (i) design maximum throughput and turn-down ratio in both open and closed loop operation. For closed loop operation, the maximum available heat input is also to be stated;
  (ii) design maximum discharge gas pressure and minimum gas superheat;
  (iii) the maximum and minimum permissible variations from the design operating conditions;
  (iv) the maximum permissible back pressure allowed in the gas send-out system;
  (v) design maximum transfer rates where ship LNG transfer is undertaken and the method and control used to handle boil-off gas and displacement gas to and from the offloading vessel;
  (vi) the minimum required gas output for a specific sea-water temperature and throughput, when applicable;
  (vii) for open loop systems the maximum LNG throughput at various seawater inlet temperatures;
  (viii) for closed loop systems the output of the boiler or alternative heating arrangement;
  (ix) for open loop systems the minimum allowable sea-water outlet temperature;
  (x) for closed loop systems the design minimum temperature and throughput of the heated water or heat transfer fluid.
(c) Procedures for connecting/disconnecting the gas send-out pipeline and LNG transfer arms or hoses. Details of the isolation arrangements and inerting and gas-freeing of the send-out and LNG pipework;
(d) Emergency procedures to be followed during regasification and barge or offshore unit-to-ship operations. These shall include guidance on procedures to be followed in the event of closure of the land-based send-out gas master valve;
(e) Specified availability and extent and periodicity of contract down-time.

2.2.3 Risk based analysis undertaken to a recognised Standard in accordance with LR's ShipRight procedure '*Assessment of Risk Based Designs*' and the associated Annex on LNG. The analysis shall be documented so that the risks and how they are eliminated or mitigated are clearly identified, and an appropriate level of safety, dependability and hazardous area classification is demonstrated.

2.2.4 Regasification barge or offshore unit general arrangement. Plans showing the arrangement of all areas where equipment, components and piping systems are located.

2.2.5 Plans for vaporisers, heat exchangers (shell/tube, printed circuit and plate type), LNG drum, liquid receivers and other pressure vessels (*see also Pt 5, Ch 11 Other Pressure Vessels*).

2.2.6 Plans and documents as required by *Pt 6, Ch 1 Control Engineering Systems*, showing the automatic controls, alarms and safety systems associated with the regasification system.

2.2.7 The thermodynamic calculations confirming the design send-out rates for the vaporisers.

2.2.8 Capacity calculations for pressure relief valves and discharge pipe vent stack pressure drop calculations.

2.2.9 Piping information is to include:

(a) schematic plans, including full particulars of piping and instrumentations for:
  (i) low and high pressure LNG supply pipework;

(ii) primary and secondary thermal fluid systems;
(iii) heating system for closed loop operation;
(iv) depressurisation system (knock-out drum and shock load verification arrangements);
(v) barge or offshore unit LNG manifold and transfer arrangements;
(vi) high pressure gas send-out systems;
(vii) cooling water systems;
(viii) other associated ancillary systems.

(b) details of means of draining, inerting, and gas-freeing of the regasification pipework, equipment and components;
(c) pipework and equipment insulation arrangements;
(d) protection of barge or offshore units structure, pipework and equipment against cryogenic leakage;
(e) pipe stress analysis. A complete stress analysis as required by *Pt 11, Ch 5, 5.2 Stress aspects 5.2.3* of applicable pipework.

2.2.10 Hazardous Area Plan for regasification equipment and send-out system.

2.2.11 Interfaces: plans and documents detailing the barge or offshore unit to regasification system interfaces.

2.2.12 Safety system plans: fire-fighting details, gas detection details, fire and general alarm details, all related to the regasification system and to the send-out arrangements. They shall be included in the main safety system plans of the vessel for approval in accordance with these Rules.

2.2.13 Escape plan: details of the arrangements for protection and safe escape in relation to the regasification system and send-out arrangements.

2.2.14 An emergency shutdown (ESD) system cause and effect matrix that shall cover the additional operational scenarios of regasification and barge or offshore unit LNG transfer. This shall be integrated with the ESD main system matrix of the vessel. Where an ESD initiation results in multiple actions, the matrix shall indicate these in the order in which they will be performed.

2.2.15 A functional flow chart of the ESD system and connected systems shall be provided which aligns with the cause and effect matrix and details the functions provided by ESD System. A copy shall be maintained at the regasification control station and on the central control room.

2.2.16 A process shutdown (PSD), cause/effect matrix and design philosophy.

2.2.17 Details of depressurisation and high pressure blowdown philosophy and arrangements.

2.2.18 Ancillary systems or additional equipment such as blending facilities, odorizers, dew point correction/ dehumidification, control and monitoring facilities where these are to be considered as part of the classed equipment.

2.2.19 Operating manuals shall be submitted. The content of the manuals shall include but not be limited to:

(a) particulars and a description of the systems;
(b) overall operation of the system, including procedures for planned start-up and shutdown;
(c) maintenance instructions for the installed equipment, systems and arrangements;
(d) temperature and pressure control systems;
(e) system limitations, including minimum temperatures, maximum pressures, transfer rates;
(f) special procedures associated with fire-fighting where different from barge or offshore unit's systems;
(g) details of fixed gas detection where additional to the barge or offshore unit's fitted systems;
(h) control, alarm and safety systems;
(i) emergency and process shutdown systems, including pressure relief and blowdown;
(j) emergency procedures, including isolation from LNG storage tank.

■ *Section 3* Risk based analysis

3.1 Purpose

3.1.1 The purpose of the risk based analysis is to:

(a) evaluate safety considerations that are specific to the regasification and send-out equipment, *see Pt 11, Ch 20, 3.2 System safety risk assessment*;
(b) evaluate dependability of the regasification plant, *see Pt 11, Ch 20, 3.3 System dependability*;
(c) specially consider arrangements which deviate from the requirements of these Rules, *see Pt 11, Ch 20, 3.2 System safety risk assessment*.

3.2 System safety risk assessment

3.2.1 The objectives of the assessment are to:

(a) Evaluate safety risks associated with the use of the regasification system where the requirements within the Rules are not satisfied;
(b) Evaluate safety risks associated with the use of the regasification system where specifically required by the Rules;
(c) for (a) and (b), demonstrate that an appropriate level of safety is achieved, which is commensurate with that generally accepted for the containment of LNG cargoes through compliance with these Rules.

3.2.2 Where the risks cannot be eliminated, an inherently safer design shall be sought in preference to operational/procedural controls. This shall focus on engineered prevention of failure (e.g. minimised number of connections, increased reliability, and redundancy).

3.2.3 The risk assessment may identify the requirement for safety measures in addition to those specifically stated in these Rules.

3.2.4 The scope of the risk assessment may include but not be limited to:

(a) normal operation, start-up, normal shutdown, non-use, and emergency shutdown of the system, during:

- pressurised gas discharge to shore; high pressure gas venting;
- storage and handling of flammable or toxic secondary heat transfer fluids (as applicable);
- continuous presence of liquid and vapour cargo outside the cargo containment system;
- Barge or offshore unit-LNG transfer.

(b) physical layout of machinery and equipment including extension of hazardous areas and evacuation arrangements;
(c) fire and explosion, process upset conditions, over-pressure and under-pressure, mechanical and electrical failures and human error. Consideration being given to the effects of pool and jet fires;
(d) the effect of cryogenic spills and pressurised leaks.

3.2.5 The risk assessment shall be undertaken by suitably qualified and experienced individuals to a recognised Standard (e.g. as outlined in ISO/IEC 31010-2009: *Risk management – Risk assessment techniques*) in accordance with LR's ShipRight Procedure *Assessment of Risk Based Designs* and the associated Appendix on LNG.

3.2.6 The risk assessment shall be assessed in accordance with *Pt 11, Ch 5, 8.5 Liquefied gas transfer system 8.5.2* (g), and:

(a) analysis of risk associated with the barge or offshore unit-to-ship LNG transfer in accordance with ISO 28460:2010 *Petroleum and natural gas industries – Installation and equipment for liquefied natural gas – Ship-to-shore interface and port operations* and the relevant parts of EN 1474 as applicable, and SIGTTO LNG *Ship-to-Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases*.
(b) process upsets associated with the land-based receiving systems;

3.3 System dependability

3.3.1 Where Class Notation ✠ **Lloyd's RGP+** is to be assigned, an assessment shall be carried out to demonstrate that a fault in any active component or system will not result in reduced availability of the plant to send-out gas.

3.3.2 The level of availability of the regasification system shall be specified by the Owner or operator, see *Pt 11, Ch 20, 2.2 Systems and arrangements 2.2.2*.

3.3.3 The assessment shall be undertaken by suitably qualified and experienced individuals using approaches acceptable to LR.

Section 4
System Design

4.1 General

4.1.1 Materials, components and equipment to be used in the construction of regasification systems shall be suitable for the intended service conditions and acceptable to LR. The materials, components and equipment shall also satisfy the requirements of this Section.

4.1.2 Materials shall comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2016* and *Pt 11, Ch 6 Materials of Construction and Quality Control* .

4.1.3 The design, arrangements and selection of equipment shall be such as to minimise the risk of fire and explosion from flammable products.

4.1.4 Electrical components and equipment shall comply with Section *Pt 11, Ch 20, 7 Electrical installation*.

4.1.5 Any single failure of the regasification system shall not result in a hazard that affects safety.

4.1.6 The regasification barge or offshore unit shall have adequate capability for managing the boil-off gas generated by heat ingress through headers, manifolds flexible hoses and loading arms during barge or offshore unit-to-ship transfer operations.

4.1.7 The regasification system shall include provision to pre-cool the product transfer piping system prior to barge or offshore unit-to-ship transfer operations commencing.

4.2 Vaporisers

4.2.1 The requirements of these Rules apply to various types and designs of vaporiser and process units, such as:

- Heat exchanger designs including:

  STV – Shell and tube heat exchanger type.
  PCHE – Printed circuit heat exchanger.
  AHHE – Air heated heat exchanger utilising forced ventilation.
  CWHE – Coil wound heat exchanger.
- ORV – Open rack type utilising sea-water or a circulating intermediate heated fluid.
- SCV – Submerged combustion type utilising the heat of combustion of either oil or send-out gas.

4.2.2 Vaporising units of novel design, making use of materials not covered by the Rules, will be subject to special consideration and subject to the requirements of *Pt 7, Ch 14 Requirements for Machinery and Engineering Systems of Unconventional Design* of the Rules for Ships, *'Requirements for machinery and engineering systems of unconventional design'*.

4.2.3 The manufacture, installation and testing of vaporisers, including the intermediate heat transfer vessels and pumping systems, shall be undertaken in accordance with these.

4.2.4 All LNG high pressure pumps supplying vaporisers, which are capable of developing a pressure exceeding the design pressure of the system into which they are pumping, are to be provided with relief valves in closed circuit.

4.2.5 For STVs and ORVs, sea-water may be used as a primary heat source for vaporisation. An intermediate heat transfer fluid may be proposed to reduce the chance of freezing and effects of corrosion.

4.2.6 Where sea-water is used as the source of heat to vaporise the LNG, the tubes shall be manufactured from a corrosion-resistant material, taking into consideration the type and temperature of media conveyed. Where the ✠ **Lloyd's RGP+** Notation is to be assigned, suitable redundancy of the sea-water circulation pump and LNG high pressure supply pumps shall be provided.

4.2.7 When an intermediate heat transfer fluid is used, and where the ✠ **Lloyd's RGP+** Notation is to be assigned, dual compressors or circulating pumps shall be provided. Where the heat transfer fluid goes through a phase change, the applicable Sections of *Pt 6, Ch 3 Refrigerated Cargo Installations* shall be complied with.

4.2.8 Where potential risk of failure of a tube or passage could result in gas entering the sea-water side:

(a) the sea-water side shall be designed to accept the full gas pressure of the gas side;

(b) the sea-water side shall be protected with bursting discs or relief valves in readily visible positions; the discharge from these bursting discs or relief valves shall be taken to a suitable high-pressure venting arrangement and the number and position of bursting discs or relief valves shall be adequate to relieve the flow occurring due to failure of a single tube.

4.2.9 If steam is used in a heat exchanger containing LNG, propane or other flammable gas, the condensate shall not be passed directly back to the machinery room. The steam-condensate shall be passed through a degassing tank located in a gas-dangerous area. The vent outlet from the degassing tank shall be routed to a safe location and be fitted with a flame screen. The degassing tank shall be fitted with a gas detection and alarm system, *see Pt 11, Ch 13, 1.6 Gas detection*.

4.2.10 If the barge or offshore unit is to operate in regions where insufficient natural sources of heat are available for vaporisation, e.g. due to low sea-water temperature, the design gas output conditions shall be maintained utilising alternative means.

4.2.11 Where alternative means of heating the LNG are required, an independent gas or oil supply system shall be provided to facilitate initial start-up.

4.2.12 The regasification system may operate with a dual heat source with, for example, a mixture of heat inputs from sea-water and a boiler.

4.2.13 Where aluminium alloy vertical tubes and horizontal headers are constantly covered with sea-water, adequate protection against corrosion shall be provided.

4.2.14 Commissioning and testing of vaporisers may be undertaken by the manufacturer prior to units being installed on board in accordance with *Pt 11, Ch 20, 8.2 Commissioning regasification trials*.

4.2.15 Water supply pumps shall be fitted with suitable inlet filters. It shall be possible to remove and clean the filters whilst the regasification system remains operational. Any regasification system-related sea-water inlet shall be fitted with gratings and provision made to allow cleaning by low pressure steam or compressed air.

4.2.16 A water treatment system shall be incorporated for use with submerged combustion vaporisers to eliminate degradation of the tubes.

4.2.17 The submerged combustion vaporisers shall comply with the relevant Sections applicable to inert gas generators and steam boilers operating with boil-off gas, as applicable, stated in *Pt 11, Ch 7 Cargo Pressure/Temperature Control* and *Pt 5, Ch 10 Steam Raising Plant and Associated Pressure Vessels* and *Pt 5, Ch 11 Other Pressure Vessels*.

4.3 Gas detection system

4.3.1 In addition to the gas detection system fitted to allow compliance with *Pt 11, Ch 13 Instrumentation and Automation Systems*, a permanently installed system of gas detection and audible and visual alarms is to be fitted in:

(a) all enclosed spaces containing gas piping, liquid piping or regasification equipment;
(b) other enclosed or semi-enclosed spaces where gas vapours may accumulate;
(c) air-locks;
(d) secondary fluid expansion tanks;
(e) the condensate degassing tank.

4.3.2 Gas detection equipment is to be designed, installed and tested in accordance with IEC 60079-29-1, an is to be suitable for the gases to be detected.

4.3.3 The number and the positions of detection heads or sampling heads is to be determined with due regard to the size and layout of the semi-enclosed space or compartment and be in accordance with the equipment manufacturer's recommendations. Due regard is to be given to the air flow from compartment ventilation inlets and outlets.

4.3.4 The gas detection system serving the regasification plant may be either independent or combined with the gas detection system installed to allow compliance with *Pt 11, Ch 13 Instrumentation and Automation Systems*.

4.3.5 The gas detection is to be of the continuous monitoring type, capable of immediate response.

4.3.6 The gas detection system serving the regasification plant is otherwise to comply with the construction and Installation requirements of *Pt 11, Ch 13 Instrumentation and Automation Systems*.

4.4 Emergency shutdown (ESD) system

4.4.1 An emergency shutdown (ESD) system serving the regasification plant and sub-systems and equipment shall be fitted and shall comply with the cause and effect matrix shown in *Table 20.4.1 ESD functional arrangements* as applicable.

4.4.2 The ESD system shall be activated by the manual and automatic inputs listed in *Table 20.4.1 ESD functional arrangements*. Any additional inputs shall only be included in the ESD system if it can be shown that their inclusion does not reduce the integrity and reliability of the system overall.

4.4.3 The ESD system shall return the regasification system to a safe static condition, allowing remedial action to be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within both the liquid and vapour pipework.

4.4.4 The equipment to be shut down on ESD activation shall include manifold valves during loading or discharge, and pumps and compressors associated with transferring LNG and NG.

Table 20.4.1 ESD functional arrangements

	Pumps		Compressor systems				Valves	Link
Shutdown action Initiation	Cargo pumps/ cargo booster pumps	Spray/ stripping pumps	Vapour return compressors	Fuel gas compressors and system	Reliquefaction plant, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to barge or regas' unit/ shore link***
Emergency push buttons (*see Pt 11, Ch 20, 4.4 Emergency shutdown (ESD) system 4.4.2*)	✓	✓	✓	*See* Note 2	✓	✓	✓	✓
Fire detection on deck or in compressor house*	✓	✓	✓	✓	✓	✓	✓	✓
High level in storage tank	✓	✓	✓	*See* Notes 1 and 2	*See* Notes 1 and 3	*See* Note 1	*See* Note 4	✓
Signal from barge or regas' unit/shore link	✓	✓	✓	*See* Note 2	*See* Note 3	n/a	✓	n/a
Loss of motive power to ESD valves**	✓	✓	✓	*See* Note 2	*See* Note 3	n/a	✓	✓
Main electric power failure ('blackout')	*See* Note 5	*See* Note 5	*See* Note 5	*See* Note 5	*See* Note 5	*See* Note 5	✓	✓

KEY
* Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck
** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators
*** Signal need not indicate the event initiating ESD
✓ Functional requirement
n/a Not applicable
NOTES
1. These items of equipment can be omitted from these specific automatic shutdown initiators provided the compressor inlets are protected against cargo liquid ingress.
2. If the fuel gas compressor is used to return cargo vapour to shore, it shall be included in the ESD system only when operating in this mode.
3. If the reliquefaction plant compressors are used for vapour return/shore line clearing, they shall be included in the ESD system only when operating in that mode.
4. A sensor operating independently of the high liquid level alarm shall automatically actuate a shut-off valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full. These sensors may be used to close automatically the tank filling valve for the individual tank where the sensors are installed, as an alternative to closing the ESD valve provided at eachmanifold connection. If this option is adopted, activation of the full ESD system shall be initiated when the high-level sensors in all the tanks to be loaded have been activated.
5. These items of equipment shall be designed not to restart automatically upon recovery of main electric power and without confirmation of safe conditions.

4.4.5 The emergency shutdown system associated with the regasification system shall be designed, manufactured and tested in accordance with the principles stated in *Pt 11, Ch 5, 2.2 Cargo system valve requirements*.

4.4.6 The number and location of additional shutdown positions shall be determined by the type, number, location and position of the regasification plant, sub-systems and equipment.

4.5 Process shutdown (PSD) system

4.5.1 A process shutdown system (PSD) for the regasification system shall be arranged in accordance with the requirements listed in *Pt 11, Ch 20, 6 Instrumentation, control, alarm and monitoring*.

4.5.2 The activation of the PSD shall stop the supply of LNG to the LNG suction drum, high pressure LNG pumps and gas discharge valve. Where the installation comprises a number of separate regasification systems the PSD may be system-specific as well as initiating a full shutdown. A PSD functional arrangement matrix commensurate with that shown in *Table 20.4.1 ESD functional arrangements* shall be provided.

4.5.3 Manual PSD points shall be arranged at each regasification system's control station and at locations as determined by the type, number, location and position of the regasification systems and equipment. The process shutdown points shall be clearly indicated.

4.5.4 Process shutdown valves in liquid piping shall close fully under all service conditions within an acceptable duration of actuation. Due regard shall be given in the design of the process shutdown system to avoid the generation of surge pressures within drain pipelines and collect tanks. Information about the closing time of the valves and their operating characteristics shall be available on board and the closing time shall be verifiable and reproducible.

4.5.5 The closure time for the shutdown valve referred to in *Pt 11, Ch 20, 5.4 Piping system testing and non-destructive examination* shall be measured from the time of manual or automatic initiation to final closure and is made up of a signal response time and a valve closure time. Valve closure time shall be such as to avoid surge pressure in pipelines.

4.6 Depressurisation and blowdown system

4.6.1 In accordance with ISO 23251 or equivalent.

4.6.2 A depressurisation and blowdown system shall be provided for depressurising high pressures liquid, vapour and gas systems. Each high pressure system may contain; liquid pumps, gas compressors, vessels, heat exchangers and pipework.

4.6.3 Where a liquid depressurisation system is provided, adequate provision shall be made in the design and installation for the effects of back pressure after the blowdown valve and the resulting volume of vapour flash gas due to the pressure drop.

4.6.4 Manual and automatic activation of the depressurisation system shall be provided.

4.6.5 Manual activation shall be possible from each regasification system's control station, at the send-out manifold, and from other locations as determined by the type, number, location and position of the regasification systems and equipment. The depressurisation and blowdown system activation points shall be clearly indicated.

4.6.6 Automatic activation shall be part of the emergency shutdown arrangements.

4.7 System and pressure vessel protection

4.7.1 Each regasification system and associated pressure vessel is to be fitted with a form of secondary protection. This may take the form of pressure relief valves or alternatively an instrument-based system.

4.7.2 **Pressure relief and venting system**

(a) Each regasification unit shall be provided with safety relief valves and venting arrangements which are to be separate from the venting arrangements serving the LNG storage tanks. High pressure safety relief valves, headers, knock-out pots, collection tanks, drain drums and vent masts shall be located within the cargo deck area.
(b) High pressure safety relief valves and venting arrangements for liquid and gas shall be provided for each regasification system. The safety relief valve support arrangements shall be suitable to withstand the loads imposed by relief valve opening.
(c) Where multiple regasification systems are installed, the design of pressure safety relief and venting arrangements shall consider the maximum combined release rate.
(d) The gaseous phase safety relief valves shall be led to a dedicated high pressure vent mast for the regasification system required by (a). The high pressure vent mast shall be sized to handle the maximum regasification capacity and to ensure safe dispersal of the gas.
(e) The liquid phase safety relief valves shall be led to a knock-out pot, collection tank or drain drum having adequate capacity for the maximum LNG inflow anticipated within the design of the regasification unit. The collection vessel shall be fitted with a level switch to stop all high pressure LNG pumps. Any LNG from the collection vessel shall be safely drained back to the LNG storage tanks or be allowed to boil off and vapour to be returned to the barge or offshore unit's vapour header.
(f) LNG collection vessels shall be fitted with pressure safety relief valves in accordance with *Pt 11, Ch 5 Process Pressure Vessels and Liquids, Vapour and Pressure Piping Systems and Offshore Arrangements*.
(g) Pressure safety relief valves and venting arrangements and locations shall comply with *Pt 11, Ch 8 Vent Systems for Cargo Containment* .

4.7.3 **Instrument-based system**

(a) Instrument-based systems, in compliance with ISO 10418, may be used for both primary and secondary protection provided it is implemented in accordance with IEC 61511-1.

4.8 Fire protection and fire extinction

4.8.1 The regasification system shall be protected with both a water spray deluge system plus a dry chemical powder system and a fire detection system. The systems shall meet the requirements of *Pt 11, Ch 11 Fire Prevention and Extinction* .

4.8.2 The water spray deluge system and dry chemical powder system installed on board the barge or offshore unit shall be capable of providing coverage for the areas defined in *Pt 11, Ch 11 Fire Prevention and Extinction* and the regasification system simultaneously.

4.8.3 The barge or offshore unit's water spray deluge system shall be designed to cover the regasification equipment, barge or offshore unit-to-ship LNG flexible hoses or loading arms and gas export manifold.

4.8.4 Protection from fire and heat shall be provided as necessary for the safe escape of personnel in case of an emergency. Details shall be submitted for appraisal as indicated in *Pt 11, Ch 20, 2.1 General 2.1.1*.

4.8.5 Fire protection arrangements shall be such as to prevent possible jet fires propagating from the regasification unit to the adjacent LNG storage tank areas. Proposed arrangements shall be evaluated in the risk based studies in *Pt 11, Ch 20, 3.2 System safety risk assessment*.

4.9 Location and arrangement of equipment

4.9.1 The location of the regasification unit and its sub-systems containing LNG and NG shall be considered part of the cargo area. The regasification units and all their associated equipment shall be located as far as is reasonably possible from accommodation spaces.

4.9.2 The regasification system machinery may be located on the open deck or in cargo pump and cargo compressor rooms. Arrangements of such spaces shall be in accordance with the requirements of *Pt 11, Ch 3 Ship Arrangements*.

4.9.3 When the regasification units are located on open deck they shall be placed in a sheltered location protected from green water.

4.9.4 The locations of the system arrangements, including vaporisers, high pressure pumps, suction drums, heaters, liquid pumps and ancillary piping systems, shall be defined and evaluated in the system safety risk assessment, see Section *Pt 11, Ch 20, 3.2 System safety risk assessment*, and shall be acceptable to LR.

4.9.5 The deck plating and sub-structure of the barge or offshore unit shall be protected from possible cryogenic spills associated with the regasification unit and suction drum in way of fittings, fixtures and demountable joints. No protection will be required in locations where the deck and sub-structure material can withstand cryogenic temperatures.

■ *Section 5*
Piping requirements

5.1 General

5.1.1 Regasification system piping shall meet the applicable requirements of *Pt 11, Ch 5 Process Pressure Vessels and Liquids, Vapour and Pressure Piping Systems and Offshore Arrangements* and *Pt 5, Ch 12 Piping Design Requirements*, *Pt 5, Ch 13 Bilge and Ballast Piping Systems* and *Pt 5, Ch 14 Machinery Piping Systems*.

5.1.2 All piping, valves and fittings shall be suitable for the design operating pressures and temperatures and environmental conditions.

5.2 Materials

5.2.1 All materials used in the piping systems shall be suitable for use with the intended medium, service and ambient conditions, and shall comply with the applicable requirements of *Pt 11, Ch 6 Materials of Construction and Quality Control* and *Pt 5, Ch 12 Piping Design Requirements*.

5.3 Piping design

5.3.1 Piping between the barge or offshore unit LNG storage system and the regasification system shall be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves shall be located as close to the LNG storage tank as practicable. When the regasification unit is located in the forward section of the barge or offshore unit, such isolation shall be as near as possible to the boundary of the forward most LNG storage tank bulkhead and within the cargo area.

5.3.2 Dry break quick-release connectors shall be provided for use in an emergency in:

(a) piping between an LNG supply ship and the barge of offshore unit;
(b) send-out gas piping between the barge or offshore unit and receiving terminal.

5.3.3 A manually operated shut-off terminal valve shall be provided at the send-out manifold, in addition to any other automatic shut-off valves required, see *Pt 11, Ch 20, 4.4 Emergency shutdown (ESD) system* and *Pt 11, Ch 20, 4.5 Process shutdown (PSD) system*.

5.3.4 The spool piece, reducers, valves and other fittings to which the LNG storage system or the send-out system is directly connected shall be of approved material. They shall be of robust construction, adequately supported and suitable for the stated design conditions and manifold forces. For LNG transfer, attention is drawn to SIGTTO '*Manifold Recommendations for Liquefied Gas Carriers*'.

5.3.5 Means of draining, purging, inerting and gas-freeing the pipe lines used for the regasification system shall be provided.

5.3.6 Means of mechanical separation shall be provided between the regasification piping system and the barge or offshore unit's inert gas and nitrogen systems.

5.3.7 All main isolating valves serving the regasification systems and equipment shall be positioned in a readily accessible location.

5.3.8 The fabrication and installation of the piping associated with the regasification plant and sub-systems shall be in accordance with the relevant Sections of these Rules.

5.3.9 Provisions shall be incorporated in the design to minimise the number of flanged connections. In order to protect personnel from cryogenic burns and prevent the barge or offshore unit's structure or other carbon steel structures on deck from being exposed to brittle fracture due to LNG pressure jet, consideration shall be given to the fitting of spray shield arrangements to any flanged connection of piping containing LNG at a pressure above 10 bar g.

5.3.10 Where applicable, all LNG pipework serving the regasification system shall be suitably thermally insulated and covered with an efficient vapour barrier.

5.3.11 Both low and high pressure LNG supply pipework serving the regasification systems is to be subject to a stress analysis, taking into account ship motions and deflections.

5.4 Piping system testing and non-destructive examination

5.4.1 Testing and non-destructive examination of the regasification unit's LNG supply and gas discharge piping systems shall comply with the relevant requirements of *Pt 11, Ch 5 Process Pressure Vessels and Liquids, Vapour and Pressure Piping Systems and Offshore Arrangements* and *Pt 5, Ch 12 Piping Design Requirements*.

5.4.2 All piping systems shall be subjected to a hydrostatic test in accordance with *Table 20.5.1 Strength and leak pressure testing*. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation on board the barge or offshore unit. Joints welded on board shall be hydrostatically tested in accordance with *Table 20.5.1 Strength and leak pressure testing*. Where water cannot be tolerated or the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing means shall be submitted for special consideration by the Surveyor.

Table 20.5.1 Strength and leak pressure testing

System	Test pressure, bar g	
	Strength test	Leakage test
LNG and NG below 40 bar g	1,5 p	*See Pt 11, Ch 20, 5.4 Piping system testing and non-destructive examination 5.4.3*
LNG and NG at and above 40 bar g.	1,25 p	*See Pt 11, Ch 20, 5.4 Piping system testing and non-destructive examination 5.4.3*
NOTE p is the design pressure which is the maximum permissible pressure within the system (or part system) in operation or at rest.		

5.4.3 After assembly on board, all cargo and process piping shall be subjected to a leak test using air, halides or other suitable medium to a pressure dependent on the leak detection method applied.

5.4.4 All piping systems including valves, fittings and associated equipment for handling cargo or vapours shall be tested under normal operating conditions prior to the first regasification operation.

Section 6
Instrumentation, control, alarm and monitoring

6.1 Functional objectives

6.1.1 The regasification plant and sub-systems shall be provided with appropriate controls for safe operation of the regasification system with adequate alerts and safeguards.

6.2 Performance requirements

6.2.1 Instrumentation, control, alarm and monitoring systems shall comply with the requirements of this Section and *Pt 6 CONTROL AND ELECTRICAL ENGINEERING*.

6.2.2 The system shall be provided with automatic and/or remote controls to ensure the system operates within its design parameters.

6.2.3 A system for monitoring and indicating alerts shall be provided.

6.2.4 The system shall be provided with safeguards such as a high pressure trip, which will operate to prevent a hazard occurring or to reduce an existing hazard to persons, machinery, the barge or offshore unit or the environment.

6.2.5 Locations at which the regasification system is controlled shall be provided with a means of communication with the gas-receiving terminal.

6.2.6 The regasification system shall be provided with control, monitoring, alert and safety systems that will maintain the system throughout all normal and reasonably foreseeable abnormal conditions.

6.2.7 The system shall be provided with the alarms and shutdowns as identified by the system designer or equipment manufacturer. In the absence of such guidance, the alarms and shutdowns indicated in these Rules may be used.

6.3 Control station

6.3.1 A control station for the regasification system and barge or offshore unit-to-ship operations shall be arranged within a non-hazardous area. Emergency procedures, as defined in *Pt 11, Ch 20, 3 Risk based analysis*, concerning regasification and barge or offshore unit-to-ship transfer operations shall be capable of being performed from this station.

6.4 Communications

6.4.1 At least two means of communication shall be provided between the control station and the receiving terminal; one of these systems shall be independent of the main electrical supply.

6.4.2 Internal communication cables shall comply with the applicable requirements of these Rules.

6.4.3 The cable installation shall provide adequate protection against mechanical damage and electromagnetic interference.

6.4.4 Components shall be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and stand-by components is minimised. Duplicated communication links and equipment shall be routed to give as much physical separation as is practicable.

6.5 Equipment and systems – Alarms, shutdowns and safeguards

6.5.1 Suitable interlocks shall be provided to prevent start-up of the regasification system under conditions which could hazard the system or its equipment and components.

6.5.2 The system designer or equipment manufacturer shall identify the required alarms, shutdowns and safeguards for the design of vaporiser. The minimum shutdown requirements are indicated in *Table 20.6.1 Alarms, shutdowns and safeguards for vaporisers*.

6.5.3 The system designer or equipment manufacturer shall identify required alarms, shutdowns and safeguards for the suction drum. The minimum shutdowns requirements are indicated in *Table 20.6.2 Alarms, shutdowns and safeguards for suction drums*.

6.5.4 The control and monitoring arrangements shall be appropriate to enable the system to be controlled within the design parameters specified by the system designer or equipment manufacturer.

Table 20.6.1 Alarms, shutdowns and safeguards for vaporisers

Item	Alarm	Note
Gas discharge temperature	Very Low	Automatic shutdown
Sea-water (or heating medium) supply pressure	Very Low	Automatic shutdown
Indication of supply gas pressure to burner (SCV type)	Very Low	Automatic shutdown
Flame failure (SCV type)	Failure	Automatic shutdown
Indication of sump water level (SCV type)	Very Low	Automatic shutdown
Combustion air pressure (SCV type)	Low	Automatic shutdown
	High	Automatic shutdown
Flue gas temperature (SCV type)	High	Automatic shutdown
Gas leak detected		ESD operation (programmed)

NOTES

1. SCV type means submerged combustion vaporiser type.

2. Any additional alarms and shutdowns identified during the Risk Assessment required in Section *Pt 11, Ch 20, 3 Risk based analysis* are also to be provided.

3. The Table contains the minimum list of alarms and shutdowns for a regasification plant; additional alarms and shutdowns may be necessary as determined through risk-mitigating activities in response to a completed Risk Assessment as required by Section *Pt 11, Ch 20, 3 Risk based analysis*.

4. If certain alarms and shutdowns are not applicable for the regasification system, sufficient evidence shall be produced to support the claim and shall form part of the Risk Assessment required by *Pt 11, Ch 20, 3 Risk based analysis*.

Table 20.6.2 Alarms, shutdowns and safeguards for suction drums

Item	Alarm	Note
Suction drum pressure	Low	Automatic shutdown
Suction drum level	Very low	Automatic shutdown
Suction drum level	Very high	Automatic shutdown

NOTES

1. Any additional alarms and shutdowns identified during the Risk Assessment required by *Pt 11, Ch 20, 3 Risk based analysis* are also to be provided.

2. The Table contains the minimum list of alarms and shutdowns for a regasification plant; additional alarms and shutdowns may be necessary, as determined through risk-mitigating activities in response to a completed Risk Assessment as required by *Pt 11, Ch 20, 3 Risk based analysis*.

3. If certain alarms and shutdowns are not applicable for the regasification system, sufficient evidence shall be produced and is to form part of the Risk Assessment required by *Pt 11, Ch 20, 3 Risk based analysis*.

■ *Section 7* Electrical installation

7.1 Functional objectives

7.1.1 The electrical installation of a regasification system shall be designed, installed and maintained such that it does not represent an ignition hazard or introduce any foreseeable hazards into the normal operation of the barge or offshore unit.

7.2 Performance requirements

7.2.1 The installations shall meet with the requirements of *Pt 6, Ch 2 Electrical Engineering*, or an alternative relevant National or International Standard acceptable to LR, as applicable.

7.2.2 All electrical equipment shall be suitably protected against damage to itself under fault conditions, provide adequate protection to prevent damage to other process equipment connected to the system and to prevent injury to personnel.

7.3 System design, construction and installation

7.3.1 The electrical power for the regasification system shall be provided by an individual dedicated circuit from the main switchboard.

7.3.2 Where the ✠ **Lloyd's RGP+** Notation is assigned, the system shall be provided by two individual circuits separated in the main switchboard or section board and throughout its length and without the use of common feeders. Where a stand-by unit is provided, it shall be supplied from a separate section of the main switchboard to ensure a single point equipment failure does not render both systems inoperable.

7.3.3 Electrical equipment for the regasification system shall be suitable for use in the environmental conditions envisaged during regasification mode. It is also to be appropriately installed to prevent any adverse effects due to environmental conditions encountered when not in use.

7.4 Hazardous zones and spaces

7.4.1 The classification of hazardous zones associated with the regasification plant shall be carried out in accordance with IEC 60079-10-1 or an alternative relevant National or International Standard acceptable to LR.

7.4.2 The hazardous zones plan shall identify areas where the release of flammable gases and vapours may be present due to the regasification system during normal working operation and reasonably foreseeable abnormal conditions, as identified during the Risk Assessments required by *Pt 11, Ch 20, 3 Risk based analysis*.

7.5 Certified safe type equipment

7.5.1 Selection of electrical equipment within the hazardous zones shall be in accordance with *Pt 6, Ch 2 Electrical Engineering*.

■ *Section 8* Regasification testing and trials

8.1 Testing and trials prior to commissioning

8.1.1 During construction or conversion of the barge or offshore unit, the following additional tests and trials for the regasification system shall be carried out:

- Pressure and leak test of LNG and NG piping.
- Suction drum leak test.
- Safety valves setting.
- Function tests of fire safety systems, emergency shutdown system, process shutdown system, gas detection system, depressurising and blowdown system.
- Function tests of control, monitoring, alert and safety systems.
- Regasification heating pumps function tests.
- Verification of the requirements derived from the Risk Analysis as required by *Pt 11, Ch 20, 3 Risk based analysis*.
- Verify the equipment fails safe when subjected to a simulated failure of systems and equipment.

8.2 Commissioning regasification trials

8.2.1 The regasification trials program shall be prepared and submitted for approval. The regasification trial program shall include technical and operational information relevant to such testing.

8.2.2 Preliminary regasification trials shall consist of a running test of the regasification system with LNG low flow for the function test and shall be carried out after gas trials and before delivery.

8.2.3 The full capacity test of the regasification plant shall be carried out at an operational site.

8.2.4 The test and measurements shall be carried according to these Rules, manufacturer's standards and industry best practice.

8.2.5 After completion of the regasification trials, a report quantifying that the trials programme has been satisfactorily completed, shall be prepared and submitted. A copy of the report shall be retained on board the barge or offshore unit.

Section 1
Non-Metallic Materials

1.1 General

1.1.1 The guidance given in this Appendix is in addition to the requirements of *Pt 11, Ch 4, 5.1 Materials* where applicable to non-metallic materials.

The manufacture, testing, inspection and documentation of non-metallic materials shall in general comply with recognised Standards, and with the specific requirements of this Part as applicable.

When selecting a non-metallic material, the designer must ensure it has properties appropriate to the analysis and specification of the system requirements.

A material can be selected to fulfil one or more requirements.A wide range of non-metallic materials may be considered. Therefore the section below on material selection criteria cannot cover every eventuality and must be considered as guidance.

1.2 Material selection criteria

1.2.1 Non-metallic materials may be selected for use in various parts of liquefied gas carrier cargo systems based on consideration of the following basic properties:

Insulation – the ability to limit heat flow
Load bearing – the ability to contribute to the strength of the containment system
Tightness – the ability to provide liquid and vapour tight barriers
Joining – the ability to be joined (for example by bonding, welding or fastening).

Additional considerations may apply, depending on the specific system design.

1.3 Properties of materials

1.3.1 **Flexibility of insulating material**

The ability of an insulating material to be bent or shaped easily without damage or breakage.

1.3.2 **Loose fill material**

A homogeneous solid, generally in the form of fine particles, such as a powder or beads, normally used to fill the voids in an inaccessible space to provide an effective insulation.

1.3.3 **Nanomaterial**

A material with properties derived from its specific microscopic structure.

1.3.4 **Cellular material**

A material type containing cells that are either open, closed or both and which are dispersed throughout its mass.

1.3.5 **Adhesive material**

A product that joins or bonds two adjacent surfaces together by an adhesive process.

1.3.6 **Other materials**

Materials that are not characterised in this section of the Part shall be identified and listed. The relevant tests used to evaluate the suitability of material for use in the cargo system shall be identified and documented.

1.4 Material selection and testing requirements

1.4.1 **Material specification**

When the initial selection of a material has been made, tests are to be conducted to validate the suitability of this material for the use intended.

The material used shall clearly be identified and the relevant tests shall be fully documented.

Materials shall be selected according to their intended use. They shall:

- be compatible with all the products that may be carried
- not be contaminated by any cargo nor react with it
- not have any characteristics or properties affected by the cargo and
- be capable to withstand thermal shocks within the operating temperature range.

1.4.2 **Material testing**

The tests required for a particular material depend on the design analysis, specification and intended duty. The list of tests below is for illustration. Any additional tests required, for example in respect of sliding, damping and galvanic insulation, shall be identified clearly and documented.

Materials selected according to *Pt 11, Ch 21, 1.4 Material selection and testing requirements 1.4.1* of this Appendix shall be tested further according to *Table 21.1.1 Material testing*.

Thermal shock testing should submit the material and/or assembly to the most extreme thermal gradient it will experience when in service.

Material testing

Table 21.1.1 Material testing

Mechanical tests		X		X
Tightness tests			X	
Thermal tests	X			
Physical tests (*see* 6.9.2.5)				

(a) **Inherent properties of materials**

Tests shall be carried out to ensure that the inherent properties of the material selected will not have any negative impact in respect of the use intended.

For all selected materials, the following properties shall be evaluated:

- Density; example Standard ISO 845
- Linear coefficient of thermal expansion (LCTE); example Standard ISO 11359 across the widest specified operating temperature range. However, for loose fill material, the volumetric coefficient of thermal expansion (VCTE) shall be evaluated as this is more relevant.

Irrespective of their inherent properties and intended duty, all materials selected shall be tested for the design service temperature range down to 5°C below the minimum cargo design temperature, but not lower than –196°C.

Each property evaluation test shall be performed in accordance with recognised Standards. Where there are no such standards, the test procedure proposed shall be fully detailed and submitted to the Administration for acceptance. Sampling shall be sufficient to ensure a true representation of the properties of the material selected.

(b) **Mechanical tests**

The mechanical tests shall be performed in accordance with *Table 21.1.2 Mechanical tests*.

Table 21.1.2 Mechanical tests

Mechanical tests	Load bearing structural
Tensile	ISO 527 ISO 1421 ISO 3346 ISO 1926
Shearing	ISO 4587 ISO 3347 ISO 1922 ISO 6237
Compressive	ISO 604 ISO 844 ISO 3132
Bending	ISO 3133 ISO 14679
Creep	ISO 7850

If the chosen function for a material relies on particular properties such as tensile, compressive and shear strength, yield stress, modulus or elongation, these properties shall be tested to a recognised Standard. If the properties required are assessed by numerical simulation according to a high order behaviour law, the testing shall be performed to the satisfaction of the Administration.

Creep may be caused by sustained loads, for example cargo pressure or structural loads. Creep testing shall be conducted based on the loads expected to be encountered during the design life of the containment system.

(c) **Tightness tests**

The tightness requirement for the material shall relate to its operational functionality.

Tightness tests shall be conducted to give a measurement of the material's permeability in the configuration corresponding to the application envisaged (e.g. thickness and stress conditions) using the fluid to be retained (e.g. cargo, water vapour or trace gas).

The tightness tests shall be based on the tests indicated as examples in *Table 21.1.3 Tightness tests*.

Table 21.1.3 Tightness tests

Tightness tests	Tightness
Porosity/Permeability	ISO 15106 ISO 2528 ISO 2782

(d) **Thermal conductivity tests**

Thermal conductivity tests shall be representative of the lifecycle of the insulation material so its properties over the design life of the cargo system can be assessed. If these properties are likely to deteriorate over time, the material shall be aged as best as possible in an environment corresponding to its lifecycle, for example, operating temperature, light, vapour and installation (e.g. packaging, bags, boxes, etc).

Requirements for the absolute value and acceptable range of thermal conductivity and heat capacity shall be chosen taking into account the effect on the operational efficiency of the cargo containment system. Particular attention should also be paid

to the sizing of the associated cargo handling system and components such as safety relief valves plus vapour return and handling equipment.

Thermal tests shall be based on the tests indicated as examples in *Table 21.1.4 Thermal conductivity tests* or their equivalents.

Table 21.1.4 Thermal conductivity tests

Thermal tests	Insulting
Thermal conductivity	ISO 8301 ISO 8302
Heat capacity	x

(e) **Physical tests**

In addition to the requirements of *Pt 11, Ch 4, 5.1 Materials 5.1.3* (c) and *Pt 11, Ch 4, 5.1 Materials 5.1.4* (b), *Table 21.1.5 Physical tests* provides guidance and information on some of the additional physical tests that may be considered.

Table 21.1.5 Physical tests

Physical tests	Flexible insulating	Loose fill	Nanomaterial	Cellular	Adhesive
Particle size		x			
Closed cells content				ISO 4590	
Absorption/desorption	ISO 12571	x		ISO 2896	
Absorption/desorption			x		
Viscosity					ISO 2555 ISO 2431
Open time					ISO 10364
Thixotropic properties					x
Hardness					ISO 868

Requirements for loose fill material segregation shall be chosen considering its potential adverse effect on the material properties (density, thermal conductivity) when subjected to environmental variations such as thermal cycling and vibration. Requirements for a materials with closed cell structures shall be based on its eventual impact on gas flow and buffering capacity during transient thermal phases.

Similarly, adsorption and absorption requirements shall take into account the potential adverse effect an uncontrolled buffering of liquid or gas may have on the system.

1.5 Quality control and quality assurance (QA/QC)

1.5.1 General

Once a material has been selected, after testing as outlined in *Pt 11, Ch 21, 1.4 Material selection and testing requirements* of this Appendix, a detailed quality assurance/quality control (QA/QC) programme shall be applied to ensure the continued conformity of the material during installation and service. This programme shall consider the material starting from the manufacturer's quality manual (QM) and then follow it throughout the construction of the cargo system.

The QA/QC programme shall include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. These may include, for example, the effect of sunlight on some insulation materials or the contamination of material surfaces by contact with personal products such as hand creams.

The proposed procedure is to be submitted to LR for consideration. All other materials in the containment system are also to be considered and included in the aforementioned procedure.

The sampling methods and the frequency of testing in the QA/QC programme shall be specified to ensure the continued conformity of the material selected throughout its production and installation.

Where powder or granulated insulation is produced, arrangements should be made to prevent compacting of the material due to vibrations.

1.5.2 QA/QC during component manufacture

The QA/QC program in respect of component manufacture must include, as a minimum but not limited to, the following items:

(a) **Component identification**

For each material, the manufacturer shall implement a marking system to clearly identify the production batch. The marking system shall not interfere in any way with the properties of the product.

This marking system shall ensure complete traceability of the component and shall include:

- Date of production and potential expiration date
- Manufacturer's references
- Reference specification
- Reference order
- When necessary, any potential environmental parameters to be maintained during transportation and storage.

(b) **Production sampling and audit method**

Regular sampling is required during production to ensure the quality level and continued conformity of a selected material. The frequency, the method and the tests to be performed shall be defined in QA/QC program; for example, these tests will usually cover, *inter alia*, raw materials, process parameters and component checks.

Process parameters and results of the production QC tests shall be in strict accordance with those detailed in the QM for the material selected.

The objective of the audit method as described in the QM is to control the repeatability of the process and the efficacy of the QA/QC program.

During auditing, Auditors shall be provided with free access to all production and QC areas. Audit results must be in accordance with the values and tolerances as stated in the relevant QM.

1.6 Bonding and joining process requirement and testing

1.6.1 Bonding procedure qualification

The Bonding Procedure Specification and Qualification Test should be defined in accordance with an appropriate recognised Standard.

The bonding procedures shall be fully documented before work commences to ensure the properties of the bond are acceptable.

The following parameters are to be considered when developing a specification:

- surface preparation
- materials storage and handling prior to installation
- covering time
- open time
- mixing ratio, deposited quantity
- environmental parameters (temperature, humidity)
- curing pressure, temperature and time.

Additional requirements are to be included if necessary to ensure acceptable results.

The bonding procedures specification shall be validated by an appropriate procedure qualification testing programme.

1.6.2 Personnel qualifications

Personnel involved in bonding processes shall be trained and qualified to recognised Standards. Regular tests shall be made to ensure the continued performance of people carrying out bonding operations to ensure a consistent quality of bonding.

1.7 Production bonding tests and controls

1.7.1 **Destructive testing**

During production, representative samples shall be taken and tested to check they correspond to the required level of strength as required for the design.

1.7.2 **Non-destructive testing**

During production, tests which are not detrimental to bond integrity shall be performed using an appropriate technique such as:

- visual examination
- internal defects detection (for example acoustic, ultrasonic or shear test
- local tightness testing.

If the bonds have to provide tightness as part of their design function, a global tightness test of the cargo containment system shall be completed after the end of the erection in accordance with the designer's and QA/QC programme.

The QA/QC standards shall include acceptance standards for the tightness of the bonded components when built and during the lifecycle of the containment system.

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